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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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Applied Sci.
Serials

TRANSACTIONS FOR 1871.

PLACE OF MEETING AND OFFICES:
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1873.

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PREMIUMS FOR 1871.

At a Meeting of the Society, held on February 5th, 1872, Premiums of Books were awarded to:—

PERRY F. NURSEY, for his Paper "On Recent Improvements in Explosive Compounds."

THOMAS CARGILL, for his Paper "On Floating Breakwaters."

THOMAS WILKINS, for his Paper "On the Machinery and Utensils of a Brewery."

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Recent Improvements in Explosive Compounds. By Perry F. Nursey 108

Floating Breakwaters. By Thomas Cargill 146

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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PLACE OF MEETING AND OFFICES:

SOCIETY'S HALL, 6, WESTMINSTER CHAMBERS,
VICTORIA STREET, S.W.

1873.

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TRANSACTIONS, &c.

February 6th, 1871.

INAUGURAL ADDRESS

By BALDWIN LATHAM, President.

In assuming again the responsibilities of the office of President of this Society, I feel that I must crave your indulgence, as I cannot hope to give that amount of attention to the duties of the office bestowed by my immediate predecessor. I take the office with the intention of devoting as much time as I can spare from my numerous professional engagements in advancing the interests of the Society. I ask you, therefore, to bear with me in my shortcomings, and to give me your hearty co-operation and support in the discharge of my duties. Since I last had the pleasure of addressing you as President, which was at a time of the deepest distress to many members of our profession, I may congratulate you on the fact that the cloud under which our profession was partially obscured has been evidently dispersing; and I trust that before the end of the year we may rejoice together in the full return of professional prosperity.

My address, delivered to you three years ago, was principally directed to the results which had accrued from works of sanitary engineering, prosecuted throughout the length and breadth of the country. On the present occasion, after directing your attention to some matters of passing importance, it is my intention to speak of the necessity of sanitary measures. The year through which we have passed was emphatically an eventful one. We have to deplore a war between our immediate neighbours, carried on upon a scale far more gigantic than any known to modern times. We have seen that upon the prosecution of warlike measures science has been brought to bear to the fullest extent, both as a means of offence and of defence; and although we must mourn over the lasting results which are sure to arise where large masses of men have been demoralized by a training in human butchery, yet, on the other hand, we cannot but see the immense care and consideration taken, especially by the Germans, to succour the sick and wounded, and to comfort and provide for the bereaved. So that if war, on the one hand, has fanned the worst passions of the human breast, it has, on the other hand, developed the finest feelings of which human nature is susceptible; and let us hope that the kindliness so enkindled will, when this cruel war shall have terminated, overpower the demoralization and its effects, otherwise so destructive to human happiness and progress. I am sure you will all agree with me in earnestly hoping that the slight break in the din of war, now taking place, may prove the harbinger of happier times, and lead to lasting peace and prosperity.

During the past year we have to record both professional successes and failures. We may congratulate our professional brethren of Italy upon the completion of the Mont Cenis Tunnel, a work which testifies to the skill and indomitable perseverance of its projectors. The success which has rewarded this enterprise will not only be a material advantage to Italy and France, as so directly interested in it, but to many other countries also. Its completion will be of especial advantage to our own profession, as the success attending this great work will, no doubt, lead to the prosecution of similar works in various quarters of the globe, where English engineers are engaged, and where English capital will be employed.

We have to lament the loss of the ill-fated *Captain*, which you are all aware took place in the early morn of the 7th of September last. There can be little doubt that this calamity entirely arose from errors in calculating the weight of the ship; consequently it was found that the mean immersion exceeded by twenty-seven inches that which was anticipated, which in a ship with so low a freeboard was followed by fatal consequences. In the loss of the *Captain* we see the great necessity of combining theory with practice. But the experience in this case has been dearly bought in the sacrifice of so much human life. The recent inundations in Rome, and the loss of life in consequence, show how slowly improvements are adopted, and are often thwarted by personal considerations, or by the petty jealousies of authorities. Almost from the very dawn of history the fatal effects of the overflow of the Tiber have been experienced in Rome. Sir William Dugdale informs us, in his history of "Embanking and Draining," that, "to restrain the exorbitant overflowing of this stream (the river Tiber), which was not a little choked with dung, and several old buildings which had fallen into it, I find that Augustus Cæsar bestowed some cost in the clearing and scouring of it, and that after this, through abundance of rain, the low grounds about the city suffering much by great inundations thereof, the remedy in preventing the like for the future was by the Emperor Tiberius committed to the care of Atieus Capito and L'Aruntius. Whereupon it was by them discussed in the senate whether, for the moderating of the floods of this river, the streams and lakes whereby it increased should be turned another way. But to that proposal there were several objections made from sundry cities and colonies, the Florentines desiring that the Glanis might not be put out of its accustomed channel, and turned into the river Arnus, in regard much prejudice would thereby befall them. In like manner did the inhabitants of Terano argue, affirming that, if the river Nar should be cut into smaller streams, the overflowings thereof would surround the most fruitful grounds of Italy. Neither were those of Reate (a city in Umbria) silent, who refused to stop the passage of the lake Uelinus (now called the Lago de Terni) into the said river Nar. The business, therefore, finding this opposition, was let alone! After which, Nerva, or Trajan, attempted likewise, by a trench, to prevent the fatal inundations of this river—but without success." Let us now hope that the promise made by the King of Italy will be fulfilled, and that soon we may hear of the prosecution of works which will successfully remove the cause of these frequent and fatal inundations.

During the past year we have seen passed through our Houses of Parliament an Act for facilitating Compulsory Education in this country. So far as the individual members of our profession may be concerned, this measure may not be attended with direct importance; but indirectly it must be looked upon as of greatest moment. We all know that mental training develops the intellect, and fits individuals for the full appreciation of those branches of engineering which have added so much to the progress of the age; and the mental training which will be brought to bear on large masses of our population, hitherto brought up in ignorance, will certainly be the means of leading into the ranks of that large class of citizens who are put in motion by the engineering talent of the country, men better fitted to follow their several avocations.

The trade and commerce of the country may be considered to be satisfactory. The latest returns published by the Board of Trade show that the total imports exceed 295 millions of money, while the exports exceed 237 millions of money. The exports to British possessions have slightly declined, while those to foreign countries have increased. The imports from British possessions have increased, while those from foreign countries have slightly declined. In the trade of articles more especially of interest to the engineering profession, we find that the imports into the country of iron and steel, both wrought and unwrought, have increased; while the exports of machinery of all kinds, agricultural implements, and wrought and unwrought iron and steel, have increased. The greatest proportional increase in any one branch of industry is shown to be in telegraph wire and telegraph instruments, which have more than trebled the exports of any former year. From the agricultural districts of the country the returns may be considered to be satisfactory, for while there is a trifling falling off in the number of cattle, sheep, and pigs maintained in the country, the area of unproductive fallow land has been lessened, while the area of land brought under cultivation for breadstuffs has increased.

If ever there was a time when it was necessary for attention to be drawn to the necessity of the prosecution of sanitary works, and of the importance of adopting the most stringent precautions against the spread of disease, that time is the present. We all know that at this moment small-pox is making rapid inroads, and spreading far and wide in the centres of our large populations. During the past year, many provincial towns and villages have been ravaged by various epidemic types of disease—diseases which have lain dormant for years have again been discerned amongst us. It appears that all human institutions, and human thoughts and opinions, are susceptible of a wavelike action. At one period the prosecution of sanitary works is being pushed forward with great energy, at other periods the results likely to accrue from the prosecution of sanitary measures seem to be ignored, and then the prosecution of sanitary works declines. There are also times, in popular opinion, which appear to be in favour of the prosecution of sanitary works, and the stringent application of those laws that are intended to prevent the spread of disease; at other times doubts arise as to the possible benefit which will accrue from the prosecution of any such measures, and in consequence they are neglected. There cannot be a shadow of doubt that to the laxity which has been displayed in the prosecution of the vaccination laws is due, in a great measure, the progress small-pox is now making amongst our people, and the non-prosecution of sanitary measures in provincial towns and villages is the sole cause of the presence of epidemic disease.

With regard to the necessity of sanitary measures, all those who have considered the physiology of animal life must know that life and health depend upon rightly understanding and practising sanitary laws. Pure air, pure water, and nutritious food, are the three great agents for promoting health and life. Any one of these agents once used, or combining with matter of a known deleterious character, loses its vital property, and becomes, as it were, poison, unfit again to fulfil its sanitary mission until it has been exposed to those revivifying influences which will restore its vital energy. Air once used loses its vitality, and becomes unfit to sustain life; air, too, that is loaded with decomposing matter will not sustain life, because the oxygen of the air is absorbed, or used up by the organic matters which are present when undergoing decomposition; air carrying decomposing matter, or the germs of disease, is also directly injurious, because it becomes the vehicle which conveys into the human system the organic elements undergoing decomposition, which have the power to produce the same state in organic structures as exist in themselves. Consequently, the effect of breathing vitiated air, or air loaded with decomposing matter, is to lower the natural state of vitality so as to render the human subject susceptible of disease, and then the corruption of the blood takes place from contracting the poisonous elements of decomposition just as effectually as if inoculated with any known poison.

The necessity of pure water is equally as important as that of pure air. Deleterious matters present in water, as a rule, act more speedily than those present in the air, because, when conveyed in water they pass at once by the rapid process of venous absorption into the system. The food we daily eat goes to make up for the daily loss and waste, or to replace those substances which have been expired or passed away in the excretions; therefore it is important that an abundant supply of nutritious food should be provided if the human body is to be maintained in health.

If we now view the physiology of vegetable life, we shall find that oxygen, which is of such vital importance to the animal creation, is, simply as oxygen, of no special service to the vegetable kingdom; but it has been arranged, in the good order of Providence, that all agents, whether air, water, or food, that have subserved the use of animals, and having ceased to promote animal life (having been converted into agents destructive to its existence), have by this very process been made fit agents for the support of vegetable life. The vegetable kingdom utilizes those waste elements which have been cast off by the animal kingdom, and, after utilizing them, retains only those substances which the air or water had originally taken up from the animal, and, in its turn again, gives up the air, water, and food in a fit and healthful state for the use of animals. These simple facts should be well understood, for in rightly comprehending them lies the whole secret of successfully carrying out sanitary operations, and dealing in a scientific manner with those compounds which are constantly being eliminated from the animal system, and which are destined to become the food of the vegetable kingdom.

In Nature it has been provided that all those matters which have once served the animal economy, if not at once brought into contact with the vegetable kingdom, shall undergo change, so as to render them fit to be again used by the animal creation. Thus urine and fæces are capable of undergoing change. By decomposition portions escape as gases into the atmosphere, which are dispersed by the winds, and soon become food for plants. Others, again, combine with the mineral constituents of the earth. The process is not so rapid as when all these matters are taken at once to the field, but the cycle is nevertheless as complete, for, sooner or later, they all go to administer to the wants of the vegetable kingdom, and poor ignorant man alone suffers for the delay; for in the incipient stages of self-purification, the matters evolved have proved highly injurious to health and life, by either causing or aggravating the type of a certain class of disease. The cause of disease is external to the human body. It is not the natural effect of existence, but it is the penalty of neglect, abuse, and also of want. Every disease has its own type, its own specific germ of generation. Every germ of disease requires conditions suitable for its development. When the human body first contracts disease, every effort is made to throw it off by those channels provided for the excretions and waste products, and when diseases of a certain type become epidemic, the cause may be looked for in the rapid development of the germs of disease under favourable conditions. It is difficult to conceive how small an amount of matter the germ may be in zymotic diseases, and how rapidly these germs may develop. We know with what rapidity a single microscopic cell of yeast will develop countless multitudes of cells, and has the power of bringing favourable matter into a rapid state of fermentation. So it may be that a single infected person may, under favourable circumstances, become the prolific centre of infection. So easily are the seeds of disease spread, that it becomes only a matter of common prudence to strive to maintain the body in health, by removing those causes which tend to lower vital energy, and to dispose of, in an expeditious and safe way, all those matters given off by the human body, whether in health or disease; for we know that "every imprudence carries its own punishment." If air is vitiated, if water is rendered impure, or our food is improper or insufficient, the body is robbed of life-giving elements, and soon succumbs to disease and death. It is the true aim and object of the sanitary engineer to assist Nature in her great but simple operations, to facilitate the purification of the air, to remove dangerous impurities from water, to supply abundance of these life-giving elements, to remove as speedily as possible, before decomposition commences, all those matters eliminated from the animal system, together with all decomposing refuse.

Wherever masses of human beings congregate, whether in towns or villages, or in armies in the field, camp, or barrack, to a certain extent an artificial existence springs up. Each individual is no longer dependent upon himself; the habits of those around him influence his own position. The preservation of the health of every class of the community is equally important to the rich and poor. It is important to the wealthy and opulent that the poor should be kept in health, for the influence of infection once contracted in the dwellings of the poor often spreads far and wide, and is no respecter of persons. It is important to the poor man especially, as his health is his wealth.

Sanitary laws and regulations are intended to give power to communities which single individuals cannot possess—*viz.* the power to promote general measures calculated to secure or improve the state of public health. In this country it so happens that the sanitary laws, to a certain extent, are permissive, so that we see some districts in which the law is rigidly enforced, while, on the other hand, community after community is still found living in the most unsanitary condition, and disease and death reign supreme. No effort is made to remedy the state of neglect which may still be found in many undrained or ill-drained places. The local authorities are not always imbued with the true spirit of humanity; money considerations are often with them of greater importance than the questions of life and health—not unfrequently it happens that political capital is made out of sanitary agitation. The advocates of filth and dirt appeal to the breeches-pocket—too often with success—thus literally fulfilling those lines written by the poet Burns, that

> "Man's inhumanity to man
> Makes countless thousands mourn."

The authorities in many of these unsanitary towns and districts appear to overlook the hard fact, that while *they* remain inactive disease and death do not. The Secretary of State for the Home Department has had of late the power to compel communities that have neglected their sanitary duties to introduce proper measures; or he may perform the work for them. But, alas! at present, in how few places requiring attention has this power been exercised. We know in ancient times, when art and science flourished, that sanitary measures had reached a high degree of excellence; but then came a period in history when both art and science declined, and with them the prosecution of those sanitary works which were of so beneficial and useful a character,—in fact, the benefits derivable from sanitary science seem to have been forgotten and ignored, and the people sunk into the lowest depths of sanitary neglect, from which the powerful voice of plague, typhus, or cholera was the first to arouse them. Little more than a quarter of a century has elapsed since efforts were made in this country to improve the sanitary condition of the great masses of the people. But short as the period has been much good has been done, many lives have been saved, and much sickness and misery averted. If upon no other than economical grounds, it is true economy to spend some little of our earnings in the prosecution of sanitary works. Health is the capital of the labouring man. It is better to give health than alms, for an unsanitary state brings sickness, disease, and mortality, which are followed by pauperism, demoralization, and crime. Dr. Johnson says: "To preserve health is a moral and religious duty, for health is the basis of all social virtues. We can be useful no longer than we are well." In how many cases has preventible illness destroyed the prospects in life of its victims? how often has the invalid become a burden to his fellow-creatures? how often has the father of a family been stricken by typhus, and left his family chargeable to the rates? in how many cases has the loss of a paternal guide left families to grow up in a course of vice and crime, and become a permanent expense to their country?

These cases are all matters that are really past calculation, but, nevertheless, we acknowledge the broad facts. It too often happens that a man dies, and his place is taken by another, without cost to his employer, and less consideration is shown to him than would have been given to a horse or a dog, which could not be replaced without pecuniary outlay. To perish by sanitary neglect is just the same as if we take so many persons out of their homes and forcibly put them to death, and yet, if this were done, the whole nation would revolt at the crime. But in how many cases do we calmly look on while the poor and innocent victims are condemned to breathe a poisoned atmosphere, or drink poisoned water, which is just as much a crime in the eyes of humanity!

This Society has invariably given a large amount of consideration to the prosecution of sanitary measures, and in its records will be found a number of papers all bearing upon practical subjects in connection with the prosecution of sanitary works. In my last Inaugural Address I stated to you that our profession is dependent for its advancement upon many branches of art and science, needing the strength and skill of the mechanic, and the scientific knowledge and attainments of the philosopher; and that it is not the knowledge of a single individual, but the accumulated knowledge of individuals and ages, that makes up the whole profession of the engineer. This fact demonstrates the necessity that exists of each individual member of our profession making himself acquainted with the works and labours of others, by promoting the interchange of thought and ideas, and by adding as much as he individually knows to the general store of information.

It is intended during the present year to make our Society more useful in its sphere of action than it has hitherto been. In addition to the ordinary papers read at the monthly meetings, the Council have in contemplation the opening of the rooms of the Society for the purposes of debating subjects which will be brought under the attention of the members present at these meetings, and the Council hope and earnestly trust that every individual member of our Society will, either by the presentation of papers, or by his attendance at the meetings, give encouragement to the labours of the Society, and assist generally in promoting its objects, which are for the good of the Society in general, and of each individual of its own members in particular.

March 6th, 1871.

BALDWIN LATHAM, PRESIDENT, IN THE CHAIR.

THE MACHINERY AND UTENSILS OF A BREWERY.

By THOMAS WILKINS.

IN bringing the subject of this paper under notice it should be mentioned that the short time at disposal prevents the Author going so closely into the minutiæ of each separate machine or appliance as could be wished, more especially as there are so many patented articles, each claiming to be the best for the purpose for which it is intended. It will therefore be desirable to give a general idea of the relative sizes, positions, and uses of the different machines and utensils generally used in breweries, rather than to discuss the relative values of different systems of, or different patented machines for, brewing.

The size of a brewery is stated in the number of quarters of malt that can be used in one brewing; thus, a brewery having a mash tun in which twenty combs of malt can be mashed at a brewing, would be a "ten-quarter brewery," and so on—the rest of the plant being made in proportion. There were few very large breweries in this country, until within about the last hundred years. Breweries were mostly small in size, seldom more than five-quarter plants, but in some towns there were a great many of these small breweries, and on the Continent, in German towns, it was not an uncommon thing to find a regular brewers' quarter.

Until steam came into general use as a motive power, all the labour was done by hand or horse power; sometimes a water wheel was used; but it is believed that on no occasion has wind power been applied; but of late years steam has not only been used in breweries as a motive power, but also as a means of transmitting heat; so that the brewer having a boiler to supply steam to the engines, uses it also to supply steam for boiling both liquor and wort, either by forming the boiling coppers with an outer pan or jacket of iron, and passing steam through the space between that and the inner pan of the copper, or by passing the steam through coils of copper pipe fixed at the bottoms of vessels made of wood, iron, or copper, whichever of these he prefers.

In building a brewery every advantage should be taken of any favourable natural features of the locality, such as a hill-side, where the building may be arranged so that the utensils can be placed in a position one above the other in level, taking advantage of the natural slope to save labour, which might otherwise have to be expended in pumping the worts or beer about. A good supply of suitable water, or "liquor," as it is called in breweries, is also indispensable. That there is this, should always be ascertained before either building a new brewery or extending an old one. In the building, iron columns, girders, and joists should be used in preference to wooden ones. The drains should be strongly and securely made, so as to prevent their breakage, and consequent leakiness, and they should be of such a size as not easily to be choked; above all, the foundations, both of walls and columns, should have especial attention. Nothing is more annoying to a brewer than to have vessels strained and rendered leaky by their supports getting out of level, either from insufficient foundations or rotting timbers.

It will be best to consider the various articles of the plant in the order they are used in brewing. The malt is generally supplied to the brewer free from all dust and malt combs, and although in many places the brewer superintends the malting, yet as malting is not brewing, this paper will not touch upon that subject. The malt has to be slightly crushed before it is mashed. This is done by pressing it between two smooth rollers revolving in opposite directions, with their peripheries nearly in contact. In small breweries they use a machine similar to that used for bruising oats, *viz.* a wheel from 3 to 4 feet in diameter, and from 5 to 8 inches wide, and a smaller wheel or roll of the same width, but of only from 6 to 10 inches diameter; both are turned smooth, and there is a feeding apparatus to prevent choking. In large breweries it is customary to use two wider rolls of equal size; for a brewery of from fifteen to twenty quarters, rolls 12 inches wide by 15 inches in diameter would be a fair size; they should be of cast iron as hard as can be turned. Some malt mills are fitted with rolls of only half the above diameter, but from 18 to 20 inches wide. This practice is not good, as the rolls have a tendency to spring apart at the centre, barely breaking the malt there, while crushing it to powder at their ends. This inequality in the sample of crushed malt is bad; what is required is just to crack the husk so that the boiling water may quickly reach the centre part of the grain. Too much flour in the crushed malt is also bad; for similar reasons no springs should be used behind the bearings, for if anything happens to get into the mills, or the feed is not very regular, in the first case the rolls part, and allow a quantity of malt to pass through without being at all crushed, and in the latter, the malt is crushed finer when the feed is thick than when thin. Where convenient the malt mill should be placed above the grist case, and grind directly into it, so that there may be no loss of the smaller particles. The grist case should be large enough to contain the whole quantity of crushed malt to be used in one brewing. The malt hopper need not be so large if it is necessary to use a Jacob's ladder; it is preferable to use it to carry up whole malt to the malt mill placed above the grist case, even if the mill has to be placed in a very confined space, rather than to elevate the crushed malt, not only on account of the loss of the smaller particles, but because there is less waste in elevating the whole malt.

The well should be carefully prepared; it should be seen that no foul water or detrimental matter of any sort can find its way into it. The pumps most generally used have three barrels, with their cranks at angles of 120 degrees, so as to throw a constant stream; for a brewery of twenty quarters the stroke should be about 14 inches, the diameter of the barrels 4 inches, and the number of revolutions per minute twenty-eight or thirty; the suction and delivery pipes of the pump would be 4 inches diameter, and might be of cast iron. The pump raises the liquor to a large tank on the top of the brewery. This tank, which is termed the "liquor back," should be large enough to contain a supply of water for attemperating sufficient to last from Saturday till Monday; from 8 to 10 barrels per quarter of malt would be a fair size; where attemperators are not used, it will be large enough if it holds 4 barrels per quarter, unless the supply of water in the well be poor and the pumps have to be kept nearly always going, when it is well to keep a good store, for emergencies. It is usual to take a branch from the rising main of the pump in well, direct to the refrigerator, so that when the worts are being cooled the liquor is pumped direct through the refrigerator. If there is much difference between the level of the liquor back and the refrigerator, a considerable amount of power is saved by the use of this branch pipe, which would otherwise have been unnecessarily expended in raising the liquor to the height of the tank, when only required at the height of the refrigerator. There is also a further saving through the liquor in the well being several degrees colder than that in the tank, and consequently cooling the worts in a shorter time.

Next for consideration is the apparatus for boiling the liquor, with which to mash, sparge, &c. In most breweries this consists of a copper, heated by a fire beneath it; but since the introduction of steam they use in many breweries a tank of wood or iron, and boil the water by passing steam through a series of pipes arranged on the bottom. In some cases, even, the steam is blown directly into the water to be boiled, but this last plan, though cheap in first cost, is a very bad one; the steam carries with it grease and other detrimental matters from the boiler. If this tank, or, as it is called, "hot liquor back," is made of wood, it should be made in the form of a tub with staves and hoops, as those made with flat sides speedily get leaky and rot. This vessel should always be covered in closely to prevent escape of vapour, and the cover should have a tightly fitting manhole. It should be placed just below the cold liquor tank, and above the mash tun, enough difference in the level being given to empty one into the other. The hot liquor back should contain about four barrels per quarter of malt.

The mash tun is made either of good yellow deals or of oak, and has a false bottom, most generally of iron, made in several plates, so as easily to be removed for cleansing the tun. These plates are very closely perforated with holes about one-twelfth of an inch diameter, sometimes however slots that width, but about 2 to 3 inches long, are cast in them. These slots and also the small holes are about three-eighths of an inch on the bottom side of the plate, being made so much taper to prevent their blocking. The plates with slots are more expensive than the others, but some brewers prefer them. The mash tun should contain from 18 to 19 cubic feet, for every quarter of malt. Formerly, when the crushed malt had been placed in the tun, the nearly boiling hot liquor was run in, and the whole was thoroughly mixed together by men with poles, each having several cross pieces about the size of the staves of a ladder, in one end. This operation is termed mashing, and these oars are still used by some brewers, more especially where a "Steele's" or a similar machine is used. A better and more certain method of mashing was required, for it was found that in some parts of the mash tun a sort of cake or dumpling would be formed, the outside of which, consisting of a pasty mass of flour, prevented the liquor reaching the inside to extract the valuable ingredient of the malt. The machine which for many years has been fitted to mash tuns to perform this operation, is made as follows:—A circular rack with radial teeth is bolted to the sides of the mash tun; a vertical shaft is erected in bearings in the centre of the tun; this shaft is either carried some few feet above the top of the tun, or else passes through a stuffing box in the bottom, and is worked by bevel wheels from a horizontal shaft. The vertical shaft supports loosely a bearing which carries one end of a second horizontal shaft which is inside the tun, at about half its depth ; the other end of this shaft has a pinion keyed upon it. This pinion gears with, and is supported by, the circular rack before mentioned. A revolving motion is given to this horizontal shaft by bevel wheels from the vertical one, and upon it is hung a sort of rake, which, as the shaft revolves, thoroughly mixes up the mash. Sometimes there are two and even three of these rake shafts. It will be obvious that, as these shafts revolve, the pinion gearing into the fixed rack causes the whole to revolve somewhat slowly round the tun.

Of late years there have been several machines invented for the purpose of thoroughly mixing the malt and liquor as they are being delivered into the mash tun; one of the most used of these machines is Steele's patent. It consists of a cylinder connected at one end with the grist case and the pipe conveying the hot liquor, both of these openings having sluices for regulating the supply of malt or liquor; the other end is half closed. The cylinder is laid horizontally with this end over the mash tun. Through the centre of this cylinder is a shaft having iron rods about three-quarters of an inch diameter, fixed in it radially, and arranged spirally from end to end. This shaft being caused to revolve at about one hundred and twenty revolutions, the hot liquor supply is turned on, and then malt is allowed to fall through its sluices from the grist case, the two being thoroughly mashed by the revolving shaft with the spokes, and delivered into the tun at the half open end. There are several descriptions of machine of this sort, but as they are all on the same principle, mention is here made only of the one mostly used.

Another description of machine is also in use in many breweries. It consists of two concentric cylindrical cases, the inner one being pierced with numerous small holes. Into one of these cases the hot liquor is conveyed, and through the other the malt is allowed to fall, the machine being fixed to the bottom of the grist case. The only exits for the liquor from the case to which it is conveyed are the small holes already referred to, through which the head of water in the hot liquor back causes it to jet with some force into the midst of the crushed malt, thoroughly wetting every particle of it as it falls into the mash tun. There are two of these machines patented by different makers. The one patent is for the inner concentric case to contain the liquor; the other patent is for a *vice versâ* arrangement. There are several other patented machines, but those above mentioned are the ones most frequently used.

In addition to the mashing machine, the mash tun is supplied with a sparger. This vessel is similar to a Barker's mill, with this exception, the arms are pierced their entire length, and the holes are more numerous at the end than nearer the centre. The object of this machine is to distribute the hot liquor lightly over the whole surface of the malt, so as thoroughly to wash from the grains all matter valuable to the brewer. The machine, indeed, is something of a large self-acting watering-pot. The bottom of the mash tun is pierced with from three to eight holes, about one-and-a-half inch diameter, from each of which a copper pipe coated with tin conveys the wort to the underback. Each of these pipes is furnished with a cock, so that the brewer can drain the tun at any point that seems to him best.

If the height of the brewery will allow, the wort boiling apparatus is at a level lower than the underback, so that the wort will run off itself from the mash tun to the underback, and thence to the copper or boiling back. If the height is not sufficient to allow of this, the wort has to be pumped from the underback to the boiling apparatus. The underback is made to hold about two barrels per quarter of malt, and although all the worts are generally run through it, its chief use is as a receptacle for the second and third worts, while the former ones are being boiled. The boiling apparatus generally consists of a copper, with fire underneath, and sometimes, in small breweries, the same copper is used to boil both wort and liquor; but this is very inconvenient, as hot liquor is frequently wanted at times when the copper is full of wort. Some of the larger brewing coppers have a dome at top, which springs from about one-third the way down the sides, the space below the dome serving as a boiling copper, while that above the dome answers the purpose of an underback, and in a much better way, as the heat from the steam from the boiling wort in the lower part of the copper keeps the next wort collecting in the upper part or pan at a good heat.

Steam is also used for boiling worts in a similar apparatus to that used for boiling liquor; the wort boiling back, however, is seldom made of iron, but generally of wood, sometimes of copper. Most brewers have an objection to boiling worts in iron vessels, being timorous of galvanic action between the iron of the vessel and the copper of the steam pipes. Whether or no there is any real danger is a matter which has not been satisfactorily decided, but it is the opinion of some that the reason why copper has been chiefly used from time immemorial for making the utensils of brewers and others similar, is not only that it is a better conductor of heat, and less liable to oxidation, but that it is much more easy of manipulation to the required shape than iron, and being of a smoother surface, is much more easily cleaned than that metal. Some brewers prefer the more intense heat of a fire under a copper to the comparatively low temperature of steam at fifty or sixty pounds' pressure. Whether there is any difference in the result, if the same article be boiled by high-pressure steam or directly by a fire, is a question.

Another method in applying steam to the heating of liquids consists in fixing a copper pan in an iron jacket, the space between the copper and jacket being filled with steam. This apparatus is much more durable than either the boiling back with heater in it, or the ordinary copper. The heater in the boiling back is soon damaged by the men removing the spent hops, and cleaning the back, the pipes getting terribly bruised by their heavy boots and shovels, while the copper at times gets burnt, not only by the hops, sugar, &c., caking upon the bottom, and preventing the worts touching the copper, thereby allowing the fire to burn it, but also from the fact that each time the copper is emptied it is exposed to the heat of the brickwork and flues, and sometimes of the fire carelessly left on the grate during the time that passes before it can again be filled. To the fact of the steam copper being more expensive than the open pan copper, and the prejudice which prefers the use of fire to that of steam, may be attributed the reason why steam-jacketed pans are not more generally in use; nevertheless, these vessels will be more in vogue when it is better known that they will last out at least two coppers, or three to four boiling backs with heaters, and that the use of steam gives a much more sure command over the boiling of the wort, for, by regulating its supply, the temperature of the wort can be kept at the required degree, and with steam there is never any fear of the worts boiling over, as the source of heat can be entirely shut off at once. With a copper many pounds are sometimes lost by its boiling over, for though all may be done in drawing fires and opening dampers, there is no way of at once nullifying the heat stored in the brick setting. The vessel for boiling the worts should contain from three-and-a-half to four barrels per quarter, and in those heated by steam the area of heating surface should be from $1\frac{1}{5}$ to $1\frac{1}{4}$ square foot per barrel of the quantity to be boiled. When the wort has been sufficiently boiled with the hops it is drawn off, and those hops which pass with it from the boiling vessel are strained from it. In small breweries this is done by a strainer fixed in part of one of the coolers, but in larger breweries a separate vessel is used, called the hop back, the bottom of which is covered with a false bottom, similar to that in the mash tun. The hop back is made of wood or of iron, as frequently of the latter as the former material. Its size depends upon its position. If it can be placed above the coolers, so that the boiling wort runs from the copper through the hop back to the coolers, it need only be of sufficient size to prevent the hops choking the holes in the false bottom; but where, as is sometimes the case, the wort is pumped after boiling to coolers on a higher level than the copper, it is necessary to make the hop back to contain the same quantity as the copper.

The wort pumps have not been mentioned until now, because in some small breweries they can be entirely dispensed with, sufficient height being given to the building to allow of the various utensils being arranged one below the other; but in large breweries, where this would entail a building of inconvenient height, it is customary to pump the worts; if a steam boiling vessel is used, it is generally placed at the top of the building above the coolers, and near the liquor boiling back, and the wort is pumped from the underback before boiling. If a copper is used, then, to save the expense of carrying up brickwork, or columns and girders to support the brick setting, it is placed as near the ground as possible, and the worts are pumped from the hop back after boiling. The wort pumps should be of the same capacity as the liquor pump; the three-throw pump is generally used. In some instances a centrifugal pump has been used with success, but as most of the machinery of the brewery works at a slow speed, it generally would involve expensive gearing to work the centrifugal at its proper rate, and, as there is a greater wear and tear, and more liability to accident in machinery working at a high rate of speed, it is well to avoid unnecessary risk, as the breaking of a wort pump is a serious matter, on account of the consequent liability to considerable loss, through the deterioration of the wort while waiting the repair of the pump. As there is no pump more to be depended on than the three-throw bucket pump, it is advisable to use that, as least likely to get out of order. Canvas packing should always be used for wort pumps, as the leather caps generally used for this description of pump are quickly spoilt. The rising main and suction pipe of this pump should be of copper pipe, tinned.

The wort has now to be cooled down to a temperature of about sixty to sixty-five degrees, before the yeast is added to produce fermentation. This temperature, or one very nearly that, is generally used by most brewers as the best, but in some parts of England, more especially in Cambridgeshire, they are satisfied to reduce to a much higher temperature. As it would take a long time for large bodies of wort to cool down from boiling point if left in deep and narrow vessels, large shallow flats called coolers are placed in such a position in the brewhouse as to be exposed to the prevailing winds, the sides of the room in which they are situated being formed as much as possible with louvre boards, which assist in directing the current of the wind. The depth of these coolers is from four-and-a-half to nine inches, of course depending greatly on the area at disposal, for having decided upon the area of the coolers their content determines the depth. To still further assist in cooling, large fans similar to the punkahs used in India were suspended above the coolers, and worked by horse or other convenient power. Surface condensers called refrigerators have also been in use many years. These originally consisted of pipes of from two to three inches diameter, laid in the coolers, through which pipes the coldest water obtainable was passed, the current of the wort being thus gradually exposed to colder water, while the water, though it gradually got hotter, still left the apparatus considerably colder than the hot wort entering.

All the various improvements which have been made in refrigerating apparatus have been made with the object of transmitting as much of the heat of the wort to the water as is possible with a minimum expenditure of water, the object being to let the water escape from the apparatus at as nearly as possible the same heat as the wort that is entering, while the wort is reduced to almost the same temperature as the water when it enters the apparatus. The efficiency of a refrigerator may consequently be ascertained by noticing the difference in temperature of the wort and liquor at each end of the machine. If there is a considerable difference, more especially at the exit end for liquor, it is known that the refrigerator is using more liquor than should be necessary. In designing a refrigerator it is not so much necessary to have a certain surface of a thin plate of metal between the wort and the liquid, as it is so to arrange the surface that there shall be so many feet for the two to travel oppositely, that is to say, supposing one hundred feet of surface in a large number of small pipes one foot long collected inside a larger pipe, and the liquor allowed to flow in at one end and out of the other of the large pipe, and the wort through the small pipes in an opposite direction, we should find a certain reduction in the temperature of the wort, and a rise in that of the water. If half the number of small pipes were used, and the length doubled, we should find on passing the same quantity of liquor or wort, that the difference would be more than in the first instance, and as we gradually diminished the number of pipes and increased the length, we should find that the difference in temperature would increase, but in a diminishing ratio, to the increase in length when a certain length had been reached. Of course the operation would take longer in the smaller number of pipes than in the larger number. It is therefore desirable in designing a refrigerator, to ascertain what quantity of wort is to be passed through per hour; then to make the wort passages amply large enough for that quantity of wort to flow through with a pressure of only one foot fall from the cooler. This regulates what may be called the width of the surface in contact. The length is made as long as desirable, taking into consideration, first, that the longer the surface the less the quantity of liquor required; and, secondly, that above a certain length the ratio of increase in the difference of temperature to the increase of length is so small as to be practically valueless. An equal total area being taken, a length of travel of about a hundred feet gives the best results. In places where there is a scarcity of water, a refrigerating apparatus, such as Messrs. Siebe Brothers' ice-making machine, may be used to advantage, and indeed it is a matter for consideration whether such an apparatus would not cost less to work than it costs to pump the large quantity of liquor required for refrigerating purposes.

When the worts have been cooled to the desired degree, they are collected in fermenting tuns, of which it is desirable to have different sizes, so that a small or large brewing can be made as desired. It is necessary to have at least four tuns containing from three to four and a half barrels per quarter. This number would be sufficient, if the beers were not cleansed in the tuns, but in many breweries the yeast is skimmed from the surface of the beer in the fermenting tuns, and, as they are consequently in use a longer time for each brewing, it is necessary to provide two or three more. Attemperators are sometimes placed in the fermenting tuns; these consist of coils of tinned copper pipe, through which hot or cold liquor can be passed. Brewers differ greatly as to the utility of attemperators; some would not be without them, while others would not have them as a gift.

It has been mentioned that the yeast is sometimes skimmed from the surface of the beer in the fermenting tuns. Where this is not the case, various methods of cleansing have been adopted. The oldest and most common is to take the ordinary casks, fill them with the fermented beer, and place them upon long troughs (called stillions) with the bung-hole uppermost. The yeast works through the bung-hole, and falls down the sides of the cask into the trough, where whatever beer has worked over with the yeast settles to the bottom of the trough, and is drawn off. The casks on the stillions are kept full by men pouring in small quantities of these settlings or other beer of the same brewing.

To save labour, several improved forms of this apparatus have been designed. The union casks used in many breweries are merely an improvement on this old method. They consist of a number of casks containing about three barrels each; each cask has trunnions fixed to the centre of each head, by which they are suspended in two rows, end to end, in a framework. Along the centre of the framework is a wooden trough, just above the casks, in which trough the yeast is collected. The bung-holes of the barrels are fitted with a gun-metal washer, in which another washer or hollow plug is ground to fit. The second washer is soldered on the end of the long leg of a horse-shoe bend, the short end of the same being open over the yeast trough. The weight of this bend is sufficient to make a joint in the washer; the gas escaping from the beer causes the yeast to work off through the horse-shoe bend. A copper pipe passes from end to end of the frame between the two rows of casks, and is connected by branches with union joints to each of the casks. Some of these branches are fitted with a cock, so that, if required, as in the case of a small brewing, only some of the casks are filled. It is necessary that the casks in use should be always full, and it is for this reason that cocks are provided to shut some off. The main pipe with the branches is connected by a pipe with the yeast trough, so that the drainings of the yeast pass through of their own weight to the casks, and keep them constantly full. This apparatus saves a considerable amount of labour, as when filled it keeps on working of itself, until the beer is thoroughly cleansed, and being self-acting it is more to be depended upon. When working upon stillions the men sometimes forget to keep the casks full.

Another form of cleansing apparatus mostly used in stout or porter breweries, consists of a series of deep tubs, with heads fixed in at an angle slightly out of square with the centre of the tubs. At the highest edge of each head a hole about 8 inches square is cut through, and a spout is fitted which hangs over the edge and side of the tub. A number of these tubs called pontos being set in two rows, a yeast trough is placed beneath the overhanging spouts; a small tub in which the settlings are collected is placed under one end of the yeast troughs; above the set of pontos is another small vessel which is kept partly full of beer, and the settlings from the yeast trough are occasionally pumped up by hand into this small tank, beneath which is hung a small tub connected to the several pontos in just the same manner as the unions before referred to; in this small tub a ball-cock at the end of a pipe from the tank above is placed at such a level so as to keep the pontos just full of beer.

There is another apparatus very similar to this in principle.

Instead of a number of tubs, a long tank is made of slate. This tank is divided longitudinally into three compartments, the partitions being made lower than the sides of the tank. The outside compartments are subdivided, so that various size brewings can be accommodated. These are filled with the beer to be cleansed, and the central space is used as a yeast trough. A small slate tank is fixed above one end as a filling-up tank, and the pipes and float apparatus are similar to those used for the pontos.

It should be mentioned that the English method of fermenting and cleansing differs from that in vogue on the Continent, where the beer to be fermented is kept at a much lower temperature than in England; the fermentation consequently does not proceed so quickly, and the yeast formed, instead of being carried by the escaping gas to the surface of the beer, collects as a sediment at the bottom of the tun, the beer being drawn off from the yeast. It is probable that this different method of fermentation has something to do with the difference in flavour between Continental and English beer.

The beer when cleansed is run off from the cleansing apparatus into settling backs, from which it is either drawn off into store vats or else into casks for immediate use. When beer is made to send to a distance, as for export, it is customary to reduce it to a lower temperature than when it leaves the cleansing apparatus, so that there may be less fear of its forcing out the bungs of the cask, or so quickly getting sharp. This decrease in temperature causes flatness, and is effected by attemperators in the settling backs similar to those in fermenting tuns.

Although the whole of the various apparatus necessary for a brewery have now been described, there are several others which have from time to time been designed to supersede manual labour. It is not necessary that the engine should be referred to here, other than to mention the size that is required. It never happens that all the machinery of the brewery must be at work at once, so that, except perhaps in some very large breweries, it is not necessary to have the malt mill at work when the liquor pumps are, or the wort pumps, mashing machine, and liquor pumps at the same time; consequently, if the engine is capable of working at most any two machines, besides the liquor pumps, it is quite large enough. In fact, a good four or five horse-power engine is sufficiently large for a twelve or fourteen quarter plant, unless the well happens to be so deep that the pumps have to be fixed considerably below the surface; then of course the power must be increased to suit the requirement.

As regards the boiler, where steam is only used for the engine, that regulates the size; but where steam is used for boiling both liquor and wort, about five or six horse-power per 10 quarters for boiling purposes in addition to the power for the engine should be allowed. The exhaust steam from the engine may be advantageously passed through a cheap heating apparatus in a tank, for the purpose of boiling water for washing casks, &c. The condensed water from the coils or other boiling apparatus should be collected in a tank, and used again to supply the steam boiler.

Several different descriptions of cask-cleaning apparatus have been designed; one of these is for washing the casks, and consists of a frame in which one or more casks partly filled with water, each containing a piece of chain or a quantity of pebbles, are fixed; the frame is made to revolve quickly in one direction, and at the same time slowly in the opposite direction. Another method for cleaning casks is to have a sort of stool or cradle, in the centre of which is a nozzle surrounded by a pad of india-rubber. The cask is placed on the stool with the nozzle in the bung-hole; the india-rubber pad forms a rough joint. Water is then injected through the nozzle, and when the cask is partly filled the water is turned off, and the steam turned on through the same nozzle. The water quickly boils in the cask, which is then rinsed out and placed aside to dry. Sometimes no water is used, the cask merely being steamed. When a cask is very bad and cannot be sweetened by ordinary methods of washing, the head is taken out and a kettle of fire is hung in it. This suggested to Mr. Robert Davidson, C.E., a process patented by him, of blowing heated air into the casks. This process was found to sweeten the casks equally as well as firing them, without the trouble of taking out the heads. Another apparatus introduced by this gentleman has in some large breweries effected a considerable saving in labour; it consists of a sort of Jacob's ladder for hoisting casks from one floor to another.

Large breweries consist generally of two or more plants. It is seldom that a single plant is more than from 60 to 80 quarters, and indeed it is scarcely wise to have them so large as this. Two 25-quarter plants will be found more manageable than one of 50. A single plant of more than 40 quarters is not to be recommended. In these large breweries where there are sometimes a dozen or more mash tuns, rather than have a large engine, it is best to have a small one to pump all the liquor, another to grind the malt, and these may be kept at work all day preparing for the morrow. Indeed a vast amount of money in first cost, and in labour afterwards, may be saved by properly planning and arranging everything beforehand.

In conclusion, the author would offer one remark which may be appropriately made applicable to other manufactories besides breweries. When it is decided to erect a new place, or to make any alteration to one already in existence, it is always best to employ some competent person to prepare the plans and specifications of the same, in accordance with which various firms may be invited to tender. If two or three manufacturing firms are asked to supply drawings and tenders, it is a very unlikely thing that they will all send the same design; consequently the comparison of the amount of their tenders will give very little notion as to which is really the cheapest; and besides, they being uncertain of obtaining the order, cannot afford to go fully into the little details. The contract is vaguely worded, and there is no chance of the purchaser knowing whether everything is included in their estimate, unless he happens to be as good an engineer and architect as he is well acquainted with his own particular business. The chances are that when the job is done the amount of extras above the estimates of the builder, backmaker, engineer, coppersmith, &c., will have reached an exorbitant sum, which might have been saved by consulting a qualified engineer in the first instance.

DISCUSSION.

Mr. King said that, with regard to rolls, he understood the author of the paper to say that some difficulty had been experienced in the feed with the malt. That was easily overcome by attaching a governor to the slide supplying the rolls; and there need be no difficulty whatever.

Mr. Colyer observed that the author mentioned a malt mill with unequal rolls. From his (Mr. Colyer's) experience such mills did not answer the purpose. Rolls of equal diameters answered the best. Referring to coppers, the author stated that jacketed pans were sometimes used. He (Mr. Colyer) believed they answered very well upon a moderate scale. Up to 20 or 25 quarters, he had seen them used with great success. With regard to false bottoms, if the holes were drilled they could not well be too small, but slots cast in the plates were a perfect failure. The only way to use slots was to have them punched by a machine. The best false bottoms were made of copper, planished, and with the holes cut out by a punch, but they were very expensive. The ordinary false bottoms used were cast iron, drilled with very small holes about two inches apart. With regard to the mashing machine, he believed that Steele's was the best outside machine, but it did not answer upon a small scale. In small breweries where, perhaps, only 10 quarters were brewed, there was a difficulty with Steele's machine. The malt got balled up when it met the hot liquor, and did not get thoroughly mashed, and it was drawn out in the tun. That, he believed, did not occur in large mashes. In many large breweries the old-fashioned mashing machine was still retained. In Burton there were no close-top coppers; they were all open-top coppers, except for boiling liquors. With regard to the galvanic action between iron vessels and copper worms, he thought it was simply a fancy. With reference to centrifugal pumps, he (Mr. Colyer) thought they answered very well upon a small scale; but he believed that ordinary three-throw pumps, worked at a low speed, with large suction and delivery pipes, were the best pumps for breweries. Coolers were not always used in breweries; in some breweries, in Burton, for instance, they were entirely done away with; but the best form of cooler he had ever seen, although they were rather expensive, were copper coolers made very thin and placed upon joists, the current of air being allowed to pass underneath as well as on the top. Some coolers were tried at Burton with Minton's tiles, but they were a perfect failure; the beer got in between the joints, and became what was called "foxy." One or two lots were spoiled in that way, and the tiles were given up. There were a great number of refrigerators in use at the present time, but he (Mr. Colyer) believed Morton's to be the best. There was also a small refrigerator lately brought out by Lawrence, which he believed was very good. The author had referred to ice-making as a means of cooling the wort. He (Mr. Colyer) believed that in the brewery with which Mr. King was connected, it was found to be the cheapest to cool the wort and not to make ice, but he believed that Siebe's apparatus was the best for that purpose. With regard to cleaning casks, he believed Pontifex's apparatus to be the best when they were fed from the centre; they were easily cleaned without disconnecting many pipes. It was important that the interior of the cask should be perfectly smooth and easily cleaned, otherwise there was a great deal of trouble. As to the pontoons which were usually used where porter was brewed, no doubt the cleanest and best were made of slate with gun-metal lipways, the same as at Truman's; they were more easily cleansed, and there was not nearly so much trouble with them as there was with wood. With respect to the cask-washing apparatus, the best plan for washing casks was to turn them over a pole. Hot liquor was let in at half or three-quarters way, and then the steam was turned on and the liquor was boiled in the cask. Where steam only was used, it was a failure. Of all the machines used for washing casks, the best was Davidson's; but at Burton very few breweries used a machine. The heads of the casks were taken out, and they were scrubbed by hand. He thought Mr. Wilkins's suggestion with reference to the engine power was good. There should be several engines about a brewery instead of one large one with complicated gear, which was very likely to get out of order.

Mr. SCAMMELL said that, with reference to unequal rolls, he would mention a case in which a pair of rolls were driven at unequal speeds. The proprietor complained about them, and when the maker went down to look at them, he noticed that one of the rolls had been unkeyed. The man said he could not possibly drive them when they were keyed on to the gearing, so he had drawn one of the keys, and ever since that they had gone very well. With regard to the question of jacketed pans, he (Mr. Scammell) would refer to one which he designed for a brewery in Northampton. In that pan, before jacketing, 90 barrels were boiled, but since the steam jacket had been introduced, a great increase had been made. A remark had been made about false bottoms, as to whether they should be drilled or slotted bottom plates. Mr. Wilkins had carried out some works for him in Ireland some years ago, in which cast false bottoms were used, and a very good job was made. The best plan, however, was to make the bottom of gun-metal cast with counter-sinks, the holes being cut through afterwards. It was expensive, but it made a very good false bottom. There were a great many mashing machines brought out, but it had generally been found that an external machine was not sufficient; it required an internal machine also, or else the grain got so solid that it could not pass. Stevens's was perhaps the best external machine. There were several self-acting machines which had been brought out, which answered their purposes very well in a small plant. The first was Maitland's, which was brought out by Henry Pontifex and Son. The grain was passed through the machine, and a small stream of water played up through it. Then there was Gregory's machine, in which the water was introduced in two or three different directions, so as to meet the grain in several ways. He thought one of the best self-acting machines was Willis's; it answered the purpose very well. There were ridges formed on the inside, so that it was impossible for any ball to go through. The Burton brewers did not use machines for cleansing, not because they would not do their work, but because the men objected to them. The brewers were afraid of the coopers; that was the real secret. Bass's had a machine, and so had Allsopp, and when they were first started, the two machines at Bass's gave very satisfactory results indeed, but the men came round in such numbers that the machines were stopped, and he believed they were standing idle to this day.

Mr. KING, referring to Mr. Colyer's remark respecting ice-machines, observed that at his brewery two had been at work for some time, and it was found to be the most economical plan, not to make ice, but to cool the water with which the wort was refrigerated direct from the machine. The four or five ton ice-machines, by cooling the water direct from the refrigerator, instead of making ice, produced results equal to thirteen and a half tons, or more than twice and a half the result it would give if ice was made.

Mr. Williams said he should be glad to know the cost of the cheapest brewing plant, which gave at the same time the best beer. A very costly plant would of course add to the price of the produce. He should like to know what the cost per quarter was with the various systems of plant, as well as the cost of those systems.

Mr. Jensen, referring to machinery for making shives and bungs used for the casks in breweries, said there was a machine brought out a few years since, by Mr. Redup, for that purpose. The usual method of making shives was by a small hand lathe, which turned them out very cheaply; but by Mr. Redup's machine they could be turned out far more quickly, and much cheaper.

Mr. Colyer observed that the yeast-press was a very important article in a brewery, especially in a large one. There were two well-known yeast-presses; one was Waller's, and the other was Needham and Kite's. There were varying opinions as to which was the best press; but he believed the latter was the best. Mr. Scammell had referred to false bottoms. He (Mr. Colyer) thought it mattered very little whether they were of gun-metal or copper; but if there was any preference to be given, he should give it to gun-metal.

Mr. Arthur Rigg said he was rather surprised to hear that slow-working machinery was not nearly so liable to get out of order as quick-working machinery. It appeared to him to be merely a question of proportion. Pumps making fourteen revolutions in a minute worked so slowly that there was no strain upon them. Fourteen revolutions was a very slow speed indeed, and consequently the pumps must be very large. He knew a pump that had been working incessantly, night and day, for about three years. It was worked at forty revolutions per minute, and there was no trouble with it. It appeared to him that the pumps used at breweries were very large and cumbersome, and worked very slowly indeed. Perhaps working at higher speeds would be cheaper.

Mr. Wilkins, in reply, said he should recommend Steele's machine in any sized brewery from five up to fifteen or twenty quarters, alone, without any other machine about it; but beyond that he should prefer rakes. Rakes answered very well; but where Steele's machine was used, it was advisable to have the liquor inlet at the bottom of the tun, so that the force of the water underneath might clear the holes in the false bottom. He remarked in his paper that unequal rolls were used in small breweries, but he did not recommend them. He thought the roll with a length equal to four-fifths the diameter was the best thing. As regarded shives and bungs, he was aware that Allsopps were using a machine for making them. It had a revolving head, in which a piece of wood was fixed, and the shive or bung was turned there; there was a tool fixed on a rest, which had four cutting edges, and which was forced into the wood; a man could cut them out very quickly. He understood Messrs. Allsopp were making the shives or bungs at a labour-cost of 3*d.* per thousand.

With regard to yeast-presses and hop-presses, they were more particularly used in large breweries. The hop-press, he believed, was preferred to the yeast-press. He knew some brewers strained the yeast through flannel, and they got the beer from that quite as well as by pressing, and saved the labour of working the machine.

Ice-making machines certainly should not be used to make ice, but, as Mr. King remarked, to cool the water. They would only be used in breweries where the water supply was limited. Coolers were going out of use; but some brewers still liked them. The difficulty was in getting rid of the last few degrees of heat. There was more cold liquor required to get wort from seventy or eighty degrees down to sixty, than was required to get it the other part of the way. He had made a few experiments with the refrigerator, taking the first wort, and the second wort, and the third wort, and noticing the time, and the quantity of liquor that was used, and the temperature in the cooler and in the tuns. It made a very considerable difference. The first wort required more of what he should call heat: it had more specific heat than the other two; that was to say, there were more units of heat in a given quantity of it than in the second and third worts, and consequently it took longer to cool. As regarded the boiler power, he had mentioned five or six horse-power—that was for boiling liquor and wort for the brewery. The power required for the engines would be extra; but he thought that five or six horse-power per 10 quarters was quite sufficient for all boiling purposes. As regarded the pumps, he said the number of revolutions was 28—not 14. What he objected to was getting up the speed to the rate of a centrifugal pump, when all the other machinery was working slowly. It would occasion the putting in of a quantity of unnecessary gearing, and the gearing of the centrifugal pump cost more than a three-throw pump would cost, and would not make such a good job in the end.

The President said that the members were much indebted to Mr. Wilkins for his paper, as very little really was known to the engineering profession in general respecting machinery used in breweries. They had also learned that it was very important to have a good supply of water, although, so far as London brewers were concerned, he believed that great difficulties arose with regard to securing that, and he did not see how it was to be obviated. A knowledge of the geology of London and the neighbourhood showed that the great water supplies, which would otherwise be available, in London, were intercepted in various directions, and percolated through the various faults in the strata, and flowed out long before they could come to the lower strata of the chalk and greensand, and very limited supplies only could be obtained, and those supplies were not of the temperature which brewers required. It appeared to him, that if the brewers could not afford to purchase water, or if the water supplied by the water companies was unsuited to brewing, the large brewing establishments would ultimately be removed out of London to those districts where there was a large supply of proper water to be procured. With regard to the general machinery and the pumps, he (the President) did not agree with three-throw pumps, which were the most uneconomical devices that could be introduced. There were many pumps with a far smaller number of valves, and which would throw a greater amount of water, and be far less liable to wear and tear than three-throw pumps; and, therefore, to lay it down as a rule that three-throw pumps were the best that could be used was certainly a mistake.

March 20*th*, 1871.

BALDWIN LATHAM, PRESIDENT, IN THE CHAIR.

BREWING APPARATUS.

By JOHN WALKER.

At the meeting for the discussion of Mr. Wilkins's paper on the utensils used in breweries, which took place at the rooms of the Society in Westminster Chambers, the following discussional paper was read by Mr. John Walker:—

It appears to me to be a matter for some regret that, in order to make his paper more interesting to the general body of engineers, Mr. Wilkins did not illustrate it with drawings, showing the various machines and utensils mentioned, and, by reference to them during the reading, enabling those who were present that had had no experience in breweries to clearly follow him, besides making the paper of more value when published in the Transactions of the Society. I would also further say, that in a paper treating on the machinery and utensils of a brewery, I think some reference might have been made, either for or against the method adopted, and the machinery and utensils used in the great breweries of Burton-on-Trent.

The author remarks that there were very few breweries in this country until within the last hundred years or so. Now, he cannot have considered Burton as being in this country in making that statement, as I believe I am right in saying that there are several firms of brewers there that have been established more than a hundred years, and fifty years ago, that is, before Burton became so celebrated for its pale ales, there were employed in the different breweries about 1000 men and boys.

In order to make good the claim that Burton has to your notice, I will here give a few particulars of the trade of the place. There are in Burton twenty-eight breweries, 105 malt houses, seventy-six ale stores or buildings devoted exclusively to the storing of ales, twenty cooperages for the manufacture of casks. The breweries cover 174 acres of land. If you take the malting season to consist of 212 days, or from September to March, the maltings are capable of producing over 300,000 quarters of malt per annum. The quantity of malt used in

Burton in 1868 was 439,000 quarters, and to produce this quantity of malt would require, say 110,000 acres of land under tillage, and the price paid to the farmer for this grain would be about 900,000*l.* The quantity of hops used in the same year was 63,000 cwt., of the value of about 500,000*l.* The quantity of ale brewed was 1,735,928 barrels; and of porter, 19,324 barrels, or a total of 1,755,252 barrels, or 63,189,072 gallons, the value of which would be 4,739,000*l.* In Burton alone, there are employed 373 heads of departments and clerks, and 4700 men and boys as labourers, at an annual salary of about 241,000*l.* In the seventy-six stores for storing ale, it is possible to stow 326,500 barrels of ale, and the number of casks in constant use in the trade is 1,472,000. There are about 200 horses and eight private locomotive engines at work in conveying material, &c., from one part of the breweries or malting premises to the other. There was also paid in the same year to her Majesty's Government for licences and taxes, from Burton, the sum of 501,800*l.* There are also about 33,000 yards of private railways in and about the breweries; also about seventy fixed engines for brewery purposes, representing considerably over 1000 horse power, and the consumption of coals is 75,000 tons per annum. The timber used for making casks, now in use in the trade, amounts to about 9,000,000 cubic feet, and the total weight of the hoops with which they are bound is 12,000 tons.

After giving you these few particulars of Burton, I will now proceed to comment on a few matters referred to by the author in his paper. He is perfectly right in advising that in building a brewery every advantage should be taken of any favourable natural features of the locality; but why a hill-side should be singled out, as of any special advantage, I do not clearly see, nor is it very clear to me that much labour will be saved by placing a brewery on a hill-side. I myself should prefer a slight inclination in the ground; and certainly in preference to a hill-side, a level piece of ground, having just sufficient natural fall for drainage purposes.

With reference to malt rollers, I have nothing to say in addition to what was said at the last meeting, only that it must be a very small brewery indeed where an oat-crushing machine is used for grinding the malt. The remark about placing the malt mill directly over the grist case can only apply where at most two mash tuns are used, as it would be somewhat expensive, and would certainly take up a great deal of room to place a pair of malt rolls over each grist case in a brewery of any magnitude.

With reference to wells, I may say for the information of gentlemen who do not know Burton, that the whole of the water used for brewing there is obtained from wells averaging about 35 feet deep, with the surface water kept carefully out, and this is of some importance where the soil has become thoroughly saturated with sewage matter, from a total want of any system of drainage, as in Burton, and in a great many parts of the town are beds of peat of considerable extent, which when opened out give off a most offensive odour, showing the vegetable matter of which it is composed is in a decaying state. No water is used for brewing from the Trent, and it is only of late years that the water from the Trent has been used to any considerable extent for cask washing or attemperating purposes. About ten years ago Messrs. Allsopp and Sons made a well on their new brewery premises 40 feet internal diameter; this well was steined in blue Staffordshire brickwork set in cement and well bound together by elm curbs and iron screw-bolts; the brick steining was about three feet in thickness.

It has often been wondered why ales could not be brewed in any other place of as good a quality as in Burton. I will place before you the following extract from the *Lancet* of some years ago which explains the matter:—

"Composition and Peculiarities of the Burton Water.

"Burton brewers have long been celebrated for the quality of their beer, and many conjectures have been made, to account for the excellence and superiority of the article brewed in that locality.

"It is the general opinion, in which, we believe, the brewers themselves concur, that their success depends to a great extent upon the quality of the well-water used.

"This water, repeated analyses have shown, contains a very large quantity of sulphate of lime, a good deal of the sulphates of potash and magnesia, and a considerable amount of carbonate of lime; the lime and magnesia, in the state of carbonate, being held in solution by carbonic acid, the excess of which is so great as to redden blue litmus paper.

"The Burton well-water, therefore, is evidently a very *hard* water, remarkable for the quantity of earthy sulphates and carbonates contained in it, and, *à priori*, it would be considered from its chemical constitution but ill adapted for the purpose of brewing. That it is not so, however, has been shown by long experience. A rational and scientific explanation of the cause of the superiority of the Burton well-water can now be afforded.

"In the course of boiling, the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are dissolved, is expelled, and these salts are precipitated; again, the alkaline phosphates present in malt have the power of decomposing and precipitating sulphate of lime, phosphate of lime, and a soluble alkaline sulphate being formed, the greater part of the phosphate of lime so formed is re-dissolved in the acid generated during fermentation. The water from being at first hard thus becomes comparatively soft, and in this state is well suited for the extraction of the active properties of the malt and hops used in the manufacture of bitter beer.

"The correctness of this explanation is clearly shown in the following analyses:—

"Analysis of the Water used in the Brewery of Messrs. Allsopp and Sons, by Dr. Henry Bottinger.

(Contents of Imperial Gallon.)

	Grains.
Chloride of sodium	10·12
Sulphate of potash	7·65
" lime	18·96
" magnesia	9·95
Carbonate of lime	15·51
" magnesia	1·70
" iron protoxide	0·60
Silica	0·79
Total solid contents	65·28

"Besides a varying quantity of carbonic acid, free, keeping the carbonates in solution. The water is remarkable for its complete freedom from organic matter.

"Analysis of Water used in the Brewery of Messrs. Bass and Co., by Mr. Cooper.

(Contents of Imperial Gallon.)

Uncombined carbonic acid, cubic inches		7·5
Carbonate of lime	grains	9·93
Sulphate of lime	"	54·40
Muriate of lime	"	13·28
Sulphate of magnesia	"	·83
Total solid contents	"	78·44

"Analysis, showing the Saline and Mineral Ingredients contained in Sample of Beer brewed by Messrs. Allsopp and Sons.

(Contents of Imperial Gallon.)

	Grains.
Alkaline sulphates, chiefly of potash	78·
Alkaline chlorides	28·
Alkaline carbonates and phosphates	14·
Phosphate of lime and magnesia, very fusible before the blowpipe	102·
Total saline and mineral ingredients	222·

"Analysis, showing the Saline and Mineral Constituents contained in sample of Beer brewed by Messrs. Bass and Co.

(Contents of Imperial Gallon.)

	Grains.
Alkaline sulphates, chiefly of potash	62·
Alkaline chlorides	25·
Alkaline carbonates and phosphates	19·
Phosphate of lime and magnesia	91·
Total saline and mineral ingredients	197·

"The two last analyses include, of course, not merely the saline constituents of the water used in making the beers, but also those of the malt and hops employed, consisting principally of phosphates.

"It will be observed that the earthy salts, the carbonates and sulphates of lime and magnesia, which impart the quality of hardness to water, have disappeared, and that the Burton water, though hard at first, really becomes a soft water, as contained in the beer.

"But the chemical constitution of the Burton water explains also another circumstance connected with Burton ales. It is known that these ales speedily become bright and clear, that they never require 'finings' to be employed, and are fit for use almost as soon as brewed.

"Now the depurating power of lime is well known, insomuch so, that it has long been employed in the clarification of cane and other vegetable juices, and it is no doubt to the presence and precipitation of this substance that the action of the Burton water in rendering the beer transparent and bright is attributable."

With reference to the remarks about pumps I must say that I prefer the ordinary three-throw pumps, such as are usually used in brewing. I of course do not mean to say that they are positively the best pumps that can be used, but I believe they are as good as any for the particular work of a brewery.

The author stated that it was usual to take a branch from the rising main of the well pumps direct to the refrigerator, so that when the worts were being cooled, the liquor was pumped direct through the refrigerator. This arrangement is very well for getting the colder water, but it certainly ought not to be the only supply to the refrigerator, as it is certainly advisable to have in addition to this another from the liquor tank, which will ensure a supply of liquor to the extent of the contents of the tank, should anything go wrong with the pumps whilst getting down the worts.

As to the apparatus for boiling liquor. Mention is made of the methods of passing steam through a series of pipes arranged at the bottom of vessels. Now I can scarcely think this a desirable plan to recommend, unless it had first been ascertained that the solid matter precipitated in boiling would not be deposited, and become fixed on the steam pipes, if fixed horizontally, and thus prevent them giving out the heat necessary for boiling. The system would not answer in Burton, nor yet with the water at Colney Hatch, which is obtained from chalk. I do not know if the author has had his attention drawn to the tanks, patented and made by Mr. Hamilton Woods for the supply of hot water. Four large tanks of this construction have recently been put up on my recommendation for the supply of hot water, for two large public institutions, and I am informed they give excellent results in working.

In the articles on brewing and breweries that appeared in *Engineering* some time ago, the following remarks were made on these tanks:—"The heating tank was constructed by Messrs. Hamilton Woods and Co. It is a circular one, thirteen feet high by seven feet nine inches diameter, and is constructed of nine plates only, the bottom being a single plate, whilst the cylindrical portion is formed of eight plates, each extending the full height of the tank. The bottom of the tank has a turned face to receive the side plates, and the edges of the latter are all planed, and the joints made as in the other tank already described. The arrangement of the heating pipes fitted to this tank is one specially used by Messrs. Hamilton Woods and Co., and is an excellent one in every respect. The two main steam passages—which are of rectangular section, six inches high by five inches wide inside—are annular, and are disposed one inside the other, there being a distance of six inches between them. Each of these main steam passages is of cast iron, and each is cast in two halves, which are bolted together. Each half of the inner passage terminates at one end in a blank flange, so the halves, when bolted together, form an annular chamber, divided by partitions into two equal divisions. One half of the outer passage has also a blank flange at one end, whilst both halves are divided midway by a partition cast in. The outer annular passage is thus divided into three chambers, one of them extending for half, and the other two each for a quarter of its circumference. The inner and outer annular passages are connected by eighteen copper pipes, each two and a half inches diameter, these pipes rising alternately to heights of five feet six inches and seven feet seven inches above the tops of the annular passages. The main passages, it will be noticed, have brackets cast on them, so that they are supported clear of the bottom of the tank, leaving plenty of room for cleaning. The steam enters through a supply pipe, into one of the shorter chambers of the outer annular casting, and thence it passes through five of the bent copper pipes into one division of the inner annular passage. From this it is led through four pipes into the larger chamber of the outer casting, round which it passes to the next five pipes, which conduct it to the second division of the inner annular passage. Finally it traverses the four remaining pipes into the other small chamber of the outer casting. With this latter chamber, and also with the second chamber of the inner and large chamber of the outer casting, waste pipes communicate, these pipes removing the water which is deposited during the condensation of the steam. It will be noticed that in this arrangement of pipes the water so deposited can fall at once to the bottom of the main passages, where it does not interfere with the main heating surface. From the manner in which the pipes are connected to the main passages, it follows also that each pipe is free to expand or contract freely without influencing its neighbours, whilst in the event of a pipe failing it can be readily removed, and either renewed or the openings with which it communicated stopped with blank flanges, without causing any but a very trifling delay. Altogether the arrangement is one which is calculated to give excellent results in practical working. Cast-iron tanks, such as we have above described, are in most instances far preferable to those of wrought iron for boiling water for brewing purposes. The objection to wrought iron is that in many cases the oxidation is so great that the vessels soon require renewal, whilst, what is worse, the water is discoloured; and, in consequence of the rust carried by it in a state of suspension, it is unfit for brewing purposes. With some kinds of water, however, a deposit is formed on the plates, which protects them to some extent from this corrosion. Cast-iron tanks are free from the above objections, and the only difficulty with them has been to make them perfectly tight under changes of temperature. This tightness can, however, be perfectly ensured by planing all the opposed surfaces of the plates, so that the joints may be made by the interposition of brown paper and mucilage, and by making the plates as large as possible so as to reduce the number of joints."

Boiling liquor by blowing the steam directly into the water to be boiled, is a method that I think no practical brewer who had to brew ales of at all a delicate nature would adopt, for the reasons just mentioned in the extract on cast-iron tanks; that is, the rust is carried in a state of suspension into the water, and renders it utterly unfit for brewing purposes on account of the colour it imparts, not only to the liquor boiled, but to the ales brewed therefrom.

As to mash tuns, I have no doubt that the best are those made of cast iron with planed joints, having no caulking whatever about them. I have heard brewers object to them because they said they discoloured the delicate pale ales brewed in them. I am of opinion that this discolouration only exists in the fancy of the brewer, and I believe it is possible to find in the markets as delicate and brilliant pale ales that have been brewed in iron mash tuns as were ever brewed in wooden ones, and the iron ones are certainly free from some most important objections that can be raised against wooden ones. They do not rot, nor are they porous, so that no bad fermentations are likely to arise from these causes, and they are particularly clean, which is another advantage they have over the wooden ones.

With respect to mashing machines, my opinion is, that no better arrangement can be made than by the use of a Steele's machine in combination with the porcupine arrangement mentioned in the paper, using the last-mentioned machine after the mash has been done by Steele's, also to set it in motion when sparging, to allow the liquor to get to every part of the mash. As to having from three to eight holes in various parts of the bottom of mash tuns for drawing off the worts, I can hardly see the advantage of this arrangement, as the false bottom keeps all the grains above it; therefore, there is nothing but wort between the false bottom and the bottom of the tun. One large-sized hole will answer every purpose, and will certainly be more manageable than a number of small cocks, with the risk of having some of them left open when they ought to be shut.

Having the wort copper domed, and using the lower part for boiling, and the domed part as an underback, cannot, I think, be a good arrangement, as there cannot be such ease in working and keeping clean as there ought to be; nor does it appear to me to permit that amount of attention to wort coppers, which is so desirable when in use, and the extra expense over the open copper and ordinary underback must be considerable.

The author of the paper, in speaking of those vessels for boiling worts by steam, says that they should have an area of heating surface of from one-fifth to one-fourth of a square foot per barrel of the quantity to be boiled. Now, taking this at one-fourth, we have 144 gallons to boil by one foot of steam-heated surface, which, at sixty pounds' pressure above the atmosphere, is equal to a temperature of 307° Fahrenheit, or 67° above boiling point. I am perhaps wrong in thinking the heating surface extremely small. I have never tried any experiments with the steam at sixty pounds' pressure for boiling; but I have recently made some experiments with steam at twenty pounds' pressure, or equal to 260°, and with almost twelve times more heating surface than that given by the author, and I did not get, by any means, the result to be desired for boiling. I believe that, in well-arranged pans for boiling by steam, the system will be found more economical than by boiling with fires. They are also more cleanly, and better to manage, and will wear out three or four of the fired ones; the first outlay is the only objection I can see to their use.

I believe the days of the large shallow flats called coolers are numbered. I look upon them now as being unnecessary, seeing that we have so many very good refrigerators, the best of which, from what I can learn, being the one patented and manufactured by Mr. Robert Morton, of Stockton-on-Tees. Mr. Colyer mentioned at the last meeting a cooler made of thin copper plate, and allowing a free circulation of air underneath, as being the best form of cooler, but he did not inform us how a cooler of this kind was to be made, so as to prevent hollow places forming in it with the weight of the wort, causing it to drag between the supports, and how he would provide sufficient strength to prevent its being damaged by the men walking upon it when cleaning after use. But considering the enormous quantity of hot water that is required in a brewery for cask washing and other cleaning purposes, of which the quantity used for refrigerating purposes would form a small proportion, and that such water as is used in the refrigerator has taken up a considerable quantity of heat in its passage through the machine, I think that, in the arrangement of a brewery, the question of how to best utilize the water so used is one that ought to be well considered.

Of ice-making machines two are now at work at Allsopps' brewery for cooling water, and not for making ice; the quantity cooled by each machine is 7000 gallons per hour; it is reduced about 6° in temperature.

The various machines that have been devised for cleaning casks, by causing them to revolve, when partly filled with water, and containing chains or pebbles, have all failed, not as was stated at the last meeting by one of the speakers, from the fear the brewers had of the Coopers' Society, but because the casks cleaned in them could not be depended upon as being thoroughly cleaned. The most difficult part to clean is the chine, or round the bevel of the head, and it was found these machines did not clean that part of a cask sufficiently to prevent them spoiling any delicate ales that were put in them. Several patented arrangements for cask cleaning are now in use, some of which give very good results. The one known as Jacob's Patent, made by Mr. John Smith, of Derby, is considered a good one, and is much used. This system is the steam and water principle. There is also another, which I am informed is giving good results, that is the one known as Allen's.

This combines with the steam and water principle a solution varying in strength according to the foulness of the vessels to be cleaned. I am informed that, besides using the solution for purifying the whole of the vessels in their breweries, such as mash tuns, coolers, squares, union casks, vats, &c., one large firm has during the last four years cleansed by this patent 100,000 casks a year.

The steam and hot-air process has been in use in Burton for ordinary casks (not stinkers) for many years. But in the large breweries all casks as they come in are unheaded and brushed out before being again filled.

As the author's attention was drawn to the fact that he had omitted to mention some very necessary machinery connected with a brewery, I do not know that I ought to bring the matters omitted from the paper forward for discussion. But I may say, that even in so small a brewery as he appears to have had in mind in preparing his paper, a hop press would be found necessary. Various methods of pressing hops have been tried, and I believe that it has been almost unanimously agreed that the best means of doing this is by hydraulic or screw pressure. Some years ago a press was tried, having a movable bed somewhat similar in principle to a Jucke's furnace. Upon this bed the hops were spread, and when the bed was set in motion the wet hops were passed between rollers, the pressure of which took out some of the moisture only, but the apparatus was not successful, and has not come into general use.

Mention was made at the last meeting about shive or bung making machines. One was used for some time at Messrs. Allsopp and Sons', but the work done by it was not considered by any means equal to that done by hand in lathes, so that it has been put out of use. An excellent little machine for making spile and porous pegs has been in use at Allsopps' brewery for many years. This machine was made by Messrs. Smith, Beacock, and Tannett, of Leeds; it is self-acting, requiring only the attention of a boy to feed it. It will turn out 10,000 porous pegs, or 6000 trial pegs per day; the price paid the boy is at the rate of 1¾*d.* per 1000 pegs made. One man at a lathe can turn out ten gross of bungs or shives per day, and is paid 6*d.* per gross. For hand-turned pegs, 1*s.* 3*d.* per 1000 is paid, and 4000 is considered a good day's work.

Barm presses, the author thought, were not necessary in an ordinary-sized brewery. I am not so sure that he is right about their not being necessary; however, if they are I can only endorse what was said at the last meeting that those by Needham and Kite are as good as any, and they have also the advantage of having been well tried, having now been in use for a great number of years.

April 3rd, 1871.

BALDWIN LATHAM, PRESIDENT, IN THE CHAIR.

THE VENTILATION OF SEWERS.

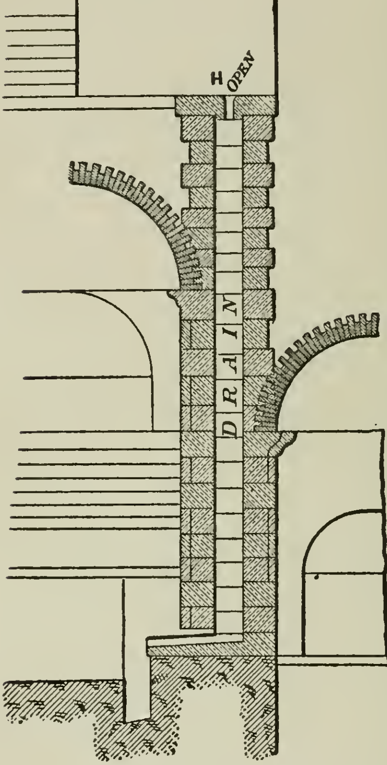
By BALDWIN LATHAM.

The bad effects of sewer air appear to have been known in the ages of antiquity. We find from Justinian's Digest—which was completed in the year 555—that the evil effects of sewer air were known and recognized before his time; for quoting Ulpian, he states that "the prætor took care that all sewers should be cleansed and repaired, for the health of the citizens, because uncleansed or unrepaired sewers threaten a pestilential atmosphere and are dangerous."

The drainage works in connection with the Coliseum of Rome show that the Romans had a very clear knowledge of what was required for the sewage of a large public building. An examination made by Mr. Cresy, as to the drainage works of this building, shows that the designer of the building introduced works of drainage as an essential feature in its construction. Within its massive walls were formed drains hewn out of the solid stone, or, in other cases, so arranged in grooves cut in the stonework, as to be entirely hidden. We also find that provision was made for collecting the sewage and rain-water, and for the prevention of the vapours or offensive effluvia from the drains entering the building—for, the drains in the outer corridor of the building, which conveyed away the sewage and rainfall, were covered by stone slabs, so arranged as to leave apertures at the sides, the space around being filled in with stone chippings, the drains from the building discharging into the space occupied by these stone chips, the liquid entering the sewer after filtering through the chippings. These chippings were covered on the top with a layer of cement, so as to prevent moisture or odour arising. Fig. 1 shows the mode adopted in the construction of the drains. It should be observed that every one of the descending drains was open at its head, and the upper end of all the drains of the building terminated in the outer corridors which were open freely to the atmosphere.

It may be noted with regard to the ancient works, in which the sewers were used to convey fæcal and other decomposable matter, that ventilation was an absolute necessity; but in the early sewer works of this country, which were principally used for the conveyance of surface water, ventilation was by no means so greatly required; but, so soon as sewers were made to convey foul matter, and to communicate directly with the interior of our houses, the means of preventing the entrance of sewer air came to be considered a matter of vital importance. The ill-effects of the non-ventilation of sewers in the early days of the revival of sanitary science, appear not to have received any marked attention; the reason probably being found in the fact that towns generally were in so bad a sanitary condition as to make it difficult to separate the causes which led to the pollution of the atmosphere. So general were nuisances, and so impure had the air of towns been rendered, that it is not surprising to find that, until sewerage works were carried out, and the principal nuisances abolished, the ill-effects of non-ventilation of sewers had not become discernible. Present experience shows, wherever the matter has received due attention, that there is something in the air of sewers dangerous to health and pestilent to life itself. The gases found in sewers are carbonic acid, nitrogen, carburetted hydrogen, sulphuretted hydrogen, ammoniacal compounds, and fœtid organic vapour.

Fig. 1.



Experiments made by Dr. Letheby on sewer water, containing 128·8 grains organic matter per gallon, when excluded from the air, gave in "nine weeks 1·2 cubic inches of gas per hour, consisting of 73·833 of marsh gas, 15·899 carbonic acid, 10·187 of nitrogen, and 0·081 of sulphuretted hydrogen." It should be noted that this is the result of a laboratory experiment, and after decomposition had been purposely allowed to take place.

In a well-constructed sewer, the decomposing matter should flow with such a velocity as to prevent stagnation; therefore the period of duration of such matter in a sewer is too short to admit of such decomposition as to lead to so large an escape of gases as is given in the foregoing experiment. When atmospheric air is present in sewers, the gases found are "carbonic acid and nitrogen, with but mere traces of sulphuretted hydrogen." The air of badly-ventilated sewers contains less oxygen than ordinary atmospheric air. Parent-Duchatell has shown that the air of a choked sewer in Paris, which was not ventilated, and after the sewage had been agitated, contained but 13·79 per cent. of oxygen; atmospheric air containing 21 per cent. It is requisite that pure air should be supplied in sewers in which men are occasionally obliged to work; therefore, in every system of ventilation, provision should be made for the admission of pure air, as well as for the discharge of foul air. The necessity for the ventilation of sewers is clearly shown by the evil effects that have arisen in those districts in which no provision has been made for ventilation, or where the arrangements have been imperfect. It is a remarkable fact, but nevertheless true, that from those towns in which no provision is made for the ventilation of the sewers, a certain type of disease—typhoid fever—is seldom absent. The evil effects of the want of ventilation were conclusively shown in the early sewerage works of Croydon, in which place no sooner were the works of drainage drawing towards completion than the town was visited by the epidemic of typhoid fever, which was traced entirely to the absence of ventilation in the system of sewerage. A reference to the mortality tables of Croydon shows that the death-rate rose from 18·53 in 1851 to 28·57 in 1853. The early sewage works were designed by Mr. Ranger, one of the superintendent engineers of the General Board of Health, and were laid out on the principle that all matters were to be so rapidly discharged from the sewers, and the sewers flushed with such a copious supply of water, that decomposition would not arise, and sewer gas therefore never be present. In the case of Croydon it was found that diseases which had hitherto made their haunt in the low-lying parts of the district were transferred, after the completion of the drainage works, to the highest or best portions of the district, thereby establishing the fact that the presence of the disease in the high localities was due to the concentration of sewer gas in the higher portions of the system of sewerage. In a system of unventilated sewers, every house in a district is placed, more or less, in communication, and, as a natural consequence, diseases may be transmitted from house to house by the sewers, when the sewer air is condensed, or brought under pressure. The temperature of the air of houses has an important bearing on the necessity of sewer ventilation. The superior temperature of the air of houses causes the various traps that are used to seal the sewers in the interior of our houses, to be relieved from pressure. Consequently, as there is less atmospheric pressure upon traps within houses, when no ventilation is provided, gases are sure to escape into houses, as the point of least resistance. It should be laid down as a rule that all sewers should be ventilated, as unventilated sewers are far more dangerous than steam boilers without safety valves. There are some persons who believe that the emanations from sewers are not dangerous, in the sense of producing disease. They base their observations on the fact that the gases which are known to be present in sewers, have not been shown to be the means of producing disease. It is true that in a dilute form many of the gases are innoxious ; but it is not probably so much the presence of these gases of known composition that is injurious, as the organic vapour and seeds of disease which are carried in the air of sewers, and which are ever active to feed or spread disease until effectually destroyed. Sewer gas escaping into the streets, and combining with large quantities of atmospheric air, is less injurious than when allowed to escape into the more limited atmosphere of our houses. It has been shown that with regard to nearly all organic poisons, there may be such a degree of dilution as completely to palliate their destructive effects. But still they may retain all their poisonous properties when again concentrated, and, moreover, pure atmospheric air has the power of oxidizing or destroying organic compounds; but when sewer air enters the generality of houses, especially at night, when the house is closed, and the whole atmosphere has been robbed of its vital properties, sewer gas carrying the elements of decomposition or the seed of disease under these circumstances becomes a deadly poison. It has been shown that not until ventilation became perfect (as at Croydon) has the death-rate been reduced to anything like a constant figure.

If we examine the forces at work within a sewer, we shall see how necessary it is that ventilation should be provided; and moreover, we shall be led to form correct opinions as to what measures should be taken for the purpose of securing perfect ventilation. The difference of temperature between the external atmosphere, and the internal air of the sewer, is one of the forces at work, by which the ventilation of sewers is affected. The following Table compiled by Mr. William Haywood, C.E., in 1858, shows the difference of temperature between the internal air of the City sewers, and the external atmosphere.

City of London Sewers.

Table showing difference of temperature between the interior of sewers and the external atmosphere (in shade).

Summary of Observations.

Time of Year.	Temperature in external atmosphere in Shade.			Temperature in Sewer.			Mean Temperature of Sewer.	
	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Above external atmosphere.	Below external atmosphere.
Summer	72	55	65·04	68	56	61·92	..	3·12
Winter	34	30	32·37	52	40	43·98	11·61	..
Spring	61	46	52·46	59	48	52·52	0·06	..
Autumn	68	48	59·90	70	53	62·97	3·07	..
Average of whole year	..	..	50·24	..	..	55·35	5·11	..

By reference to this Table it will be seen that, on the average of the year, the internal temperature of the sewers was 55·35 deg., and the external atmosphere in shade 50·24 deg.; so that, on an average of the whole year, the sewer possessed a temperature of 5·11 deg. only above that of the atmosphere. In the summer months, the average temperature of the sewer was below that of the atmosphere. In the spring, the temperature of both sewer and air was equal, while in the autumn and winter the average temperature of the sewer was in excess of that of the atmosphere. During the past year, 1870, at Croydon, on 220 days, the external air rose to a higher temperature than the highest temperature of the sewage, and on 145 days the highest temperature of the air was lower than the temperature of the sewage. There were 313 days when the external air fell to a lower temperature than the lowest of the sewage, and 52 days when the lowest temperature of the sewage was less than the lowest temperature of the external air. It may be here noted that the temperature of Croydon sewage is pretty nearly uniform during the whole year. This is due to the water supply of the district being taken from an artesian well. In the case of the City of London, the temperature of the sewers in winter was considerably below the mean temperature of the summer months, as the water supply is principally supplied from surface streams, which are subject to the same variation of temperature as the atmosphere. Barometric changes affect the amount of sewer gas present in sewers. The diminution in barometric pressure leads to the escape of gases which are stored in the interstices of the sewage, and favours decomposition. An increase of barometric pressure enables sewer air to carry a larger amount of the vapour of water. The presence of the vapour of water may be considered a force within a sewer affecting ventilation, as it gives lightness to the air. At 32 deg. the vapour of water is about one three-hundredth part ($\frac{1}{300}$) the density of air, and at 212 deg. it is nearly half as dense as air, so that, at all ordinary temperatures, the vapour of water will materially affect the density of the air in sewers. Wind blowing over the surface of ventilators in a street has a material effect in changing the currents of air within the sewers. The position of the outfall of the sewers, in reference to its exposure to the prevailing winds of the district, has also an effect upon the ventilation of the sewers. Friction and leakage both play their part as forces at work within a sewer affecting the general question of ventilation.

The force in a sewer which most materially affects the result, and which renders a system of ventilation absolutely necessary, is the varying ebb and flow of the sewage. This ebb and flow of the sewage, leaving the sides of the sewers alternately wet and dry, naturally leads to the production of much vapour or sewer-gas. The ebbing and flowing of the sewage within all sewers has also the mechanical effect of compressing or dilating the air present in the sewers. According to the law of the diffusion of gases, the pressure is inversely as the space occupied; therefore it is clear that, unless openings are made as outlets and inlets, the natural consequence of the rise and fall of the sewage in the sewer must be to expel foul air at points out of control. For example, supposing we have a sewer running half full, and that by an increase in the rate of flow it begins to run three-fourths full, the air which originally occupied half the sewer will, when the sewer runs three-fourths full, be compressed into a quarter of the sewer, and being compressed into half the space it originally occupied, its pressure would be increased by an amount equal to that of one atmosphere. Against such a pressure no traps in existence could resist the effort of the imprisoned air. It may be laid down as a rule, that in the main lines of sewer, from morn till noon sewers are expelling foul air by virtue of the rate of fluctuation of the flow, and from noon to morn they are drawing in fresh air by reason of some force being at work. Sewers discharging into the sea, or into tidal rivers, are liable to be tide-locked twice a day. During the period they are so tide-locked, as they fill up with sewage, the sewer gases will be expelled, and when the sewers discharge their contents at ebb tide, fresh air will be drawn into the system of sewerage. In consequence of this rate of fluctuation, it must be clear that all these propositions which have been made, and which will hereafter be referred to, of making down-cast and up-cast shafts, for the purposes of the ventilation of the sewers, must prove abortive, for when the sewers have within them a force which at one period naturally expels air, all shafts, whether up-cast or down-cast, will at that period become up-cast shafts; and when the air is drawn into the sewer all shafts will become naturally down-shafts. It may here be observed, that sewers themselves may act like an ordinary chimney shaft, especially in those districts in which the fall of a sewer is great, so that so long as there is an uniform rate of flow through the sewers, the tendency is for air to enter the openings at the lower points of the system of sewerage, and escape at the higher points.

There are other forces besides the fluctuation which at times modify the in-taking of air at one point, and discharging it at another. For example, the discharge of hot or cold water at points along the course of the sewer, the accidental or intentional opening of the traps in connection with house drains, which is a very common occurrence, would also modify the results. The law of the diffusion of gas tends to modify forces at work in promoting the ventilation of sewers. It also modifies the poisonous effects of the sewer air. All gases diffuse themselves through each other (although they may not combine), with a rapidity varying with the respective density of the gases. By this law light gases descend, and the heavy gases ascend, the rate of diffusion being inversely proportional to the square root of the density; as, for example, if we have two gases, one of which is four times the density of the other, the heavy gas, in this case, will therefore require twice the time the rarer gas would require to diffuse itself in an equal volume. The laws which govern ventilation are the well-known laws of gravitation, currents invariably being produced by the difference in pressure or weight of different columns of air. At 60 deg. Fahrenheit, and with a barometric pressure of 30 inches, a cube foot of ordinary atmosphere weighs 538·88 grains, or 13·06 cube feet weigh 1 lb. When the pressure of the atmosphere is equal to 14·6 lbs. to the square inch, as there are 22,570 cube inches in 1 lb. of air, that number multiplied by 14·6 will give the height of a column of air corresponding to the pressure of the atmosphere, or 329,522 inches = 27,460 feet, air would flow into vacuo with a velocity equal to that which a heavy body would acquire in falling the distance equal to the height of the atmospheric column, or with a velocity $= \sqrt{2\ g\ h}$, consequently in this case it would rush into vacuo with a velocity of $\sqrt{64 \cdot 4 \times 27{,}460} = 1330$ feet per second. Air flows from one atmosphere to another less dense with a velocity equivalent to that which would be acquired by a heavy body falling through a space equal to the difference of the respective columns of air.

The differences in pressure are arrived at by noting the differences of temperature, for temperature and pressure bear a constant ratio to each other. Air is dilated $\frac{1}{491}$ part, or, according to Rudberg's experiments, $\frac{1}{493}$ part, for every degree Fahrenheit its temperature is raised; consequently, a column of heated air, being lighter than an equal column of cold air, a difference of pressure exists, or there is a tendency for the cold air to flow into the heated air, or for the heated air to escape with a velocity equal to that which a heavy body would acquire when falling from a height equal to that of the vertical column representing the difference of pressure. A cube foot of air loses 1·097 grains in weight for each degree that it is heated. For example, supposing a ventilating shaft 60 feet high, and 1 foot sectional area, the difference in temperature between the external and internal air is 150 deg.; then 150 deg. × 1·097 × 60 feet ÷ 538·88 = 9873 ÷ 538·88 = 18·33 feet, which represent the height of the column of air that will produce motion, which in this case is equal to a pressure of 1·40 lb. per square foot. In practice, a simpler mode of calculating is adopted; for if we multiply the difference of temperature between the external and internal air by the height of the shaft, in feet, and divide the product by 491, it will give the height of the column of air producing motion. Taking the figures of the last example, it will be found that 150 × 60 ÷ 491 = 18·33 feet; the theoretical velocity created in this shaft would be equal to $\sqrt{64{\cdot}4 \times 18{\cdot}33} = 34{\cdot}35$ feet per second, or 2061 feet per minute, which also equals the discharge in cube feet, as the shaft is 1 foot sectional area. This calculation is entirely theoretical, and in practice a deduction must be made for friction. It may here be noted that the draught of a chimney 250 feet high, with a difference of 200 deg. between the external and internal air, would represent a column of air = 101·81 = to a pressure of 7·795 lbs. per foot, which is equal to a vertical column of nearly 1½ inches of water. Such a draught, therefore, would force and unseal all the ordinary traps now in use. The theoretical velocity of flow produced by this shaft would be about 55 miles per hour.

In the early sewer works of this country the gullies used for the discharge of rain-water were left untrapped, but when such sewers began to convey fæcal and decomposing matters, the gases generated were discharged by the gullies. The noxious effluvium arising from these gullies when decomposable matter came to be conveyed by the sewers was so great that it became necessary to trap them. The effect of trapping, without ventilation, brought its own train of evils, as in the case of London, and led to the adoption of a system of ventilation. Openings communicating with the sewers were formed in the centres of streets, which had the effect of removing the point of escape of the sewer air farther from the passenger traffic and from the houses, and of aiding the dilution of the escaping gases before they could reach the houses. The trapping of sewers is generally resorted to whenever any unpleasant smell is perceptible, but it should be observed that, although trapping is useful, as placing a barrier between our houses and the sewers, it cannot be depended upon unless efficient measures are adopted for providing a free escape for the foul air of the sewers. Trapping without ventilation is like locking a villain in prison, who is ever alert to effect his escape, and, when he does escape, he becomes the pest of society.

Suggestions have been made at various times to prevent the formation of sewer gas, and various expedients have been proposed to prevent the emanations arising from sewers, amongst others, by constructing the sewers of such sizes, and with such gradients, and supplying them with abundance of water for flushing, that there should be maintained through them such a high velocity, that all matters liable to decomposition should be conveyed through them with such speed that no time would be allowed for decomposition and the escape of gases. The failure of this theory, at Croydon, has already been referred to. It has also been proposed to deodorize or disinfect all materials previously to passing them into the sewers, in order to pickle or stay the period of decomposition, and so prevent noxious effluvia arising during their transit through the sewers. It has also been proposed to deodorize the sewage as it flows through sewers by various chemical agents, in order to prevent the formation of sewer gas. It has also been proposed to place within sewers absorbing materials which would absorb the sewer gases as they were generated. It has been proposed to introduce in the sewers certain chemicals, which should be slowly evaporated and destroy the noxious properties of the sewer gas. Electric and galvanic agency has also been proposed as a means of destroying the noxious properties of sewer air. It is clear that those who have proposed many of these methods of preventing the presence of sewer gas, or of destroying it, could not have been acquainted with the real nature and property of the gas, nor with the forces which are at work in every system of sewers. No one of these propositions for defecating the air of sewers would render the ventilation of the sewers less necessary.

Attempt has been made to compare the ventilation of sewers with the ventilation of mines, and the same measures which have been proposed for the ventilation of mines have been proposed in connection with the ventilation of sewers. Ventilation of sewers, although differing from that of mines, is easy and safe, and no greater mistake can be made than to confound a system of ventilation of mines with that required for sewers. In the case of a mine, it is usual to have one down-cast shaft and one up-cast shaft, or one set of down-cast shafts to convey fresh air through the workings of the mine on its way to the up-cast shaft, the circulation of the air being kept up by artificial arrangements, so as to secure the proper amount of air which should be admitted to the workings, and the discharge of the vitiated air. In a system of sewers, such a mode of ventilation as this would prove entirely inoperative, on account of the peculiar features in the construction of sewers, and the forces which are at work within the sewers themselves, whereby all untrapped openings at one period of the day become down-cast shafts, and at other periods up-cast shafts.

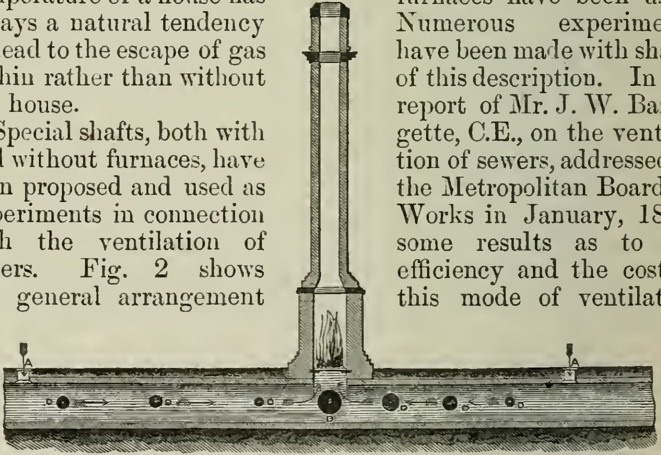
A sewer may be compared to a tube, perforated entirely throughout its length. The introduction of special means of ventilation, similar to that adopted in mines, would have the effect of causing powerful currents of air to pass into the sewer from the nearest openings, to the exclusion of a current in the more remote portions of the sewers. The means that have been proposed for effecting the ventilation of sewers are, natural ventilation and mechanical ventilation. Natural ventilation embraces all those modes which cause the air to move by reason of difference in temperature, or weight of the respective columns.

Mechanical ventilation embraces all those modes or means of producing, by machinery, currents of air, either by forcing air into or by drawing it out of sewers. When it is forced in it is called the plenum system, and when it is drawn out it is called the vacuum system. The plenum system of ventilation is not admissible in connection with a system of sewers, as the discharge of air at high pressure into sewers would naturally lead to the forcing of the traps, and the escape of the air and foul gases into the houses. The effect of the ventilation produced by drawing air out of sewers has been tried, and the results show that all these arrangements affect a very limited length of sewer.

With regard to all the modes of producing constant ventilation by artificial means, there is an objection that is fatal to the system, and it is, that every system of ventilation, which at all periods is exhausting air from the sewers, is acting in opposition to those natural forces which are at work within the sewers, and which at times demand air to be admitted, and at other times naturally cause it to be expelled. The ventilation of sewers, by means of shafts communicating with the crown of the sewer, and terminating about the centre of the roadway, is one of the expedients which has already been referred to, and which is very generally carried out in London. In the opinion of the author, this system, when furnished with suitable apparatus for absorbing and destroying the escaping vapours, is one of the best systems that can possibly be devised. With regard to the system of ventilation used in London, the causes that led to its introduction have already been referred to. The objections raised against the system are, that deleterious gases, escaping from the open shafts, are left to take their own course comparatively uncontrolled. In combating this objection, it should not be lost sight of, however, that gases escaping in the centre of roads become considerably diluted before they can arrive at the footpath or houses. The amount of dilution, supposing the gas to be uniformly distributed through the atmosphere, would be proportional to the cube of the distance from the point of discharge. These open ventilating shafts act, at certain periods, both as up-cast and down-cast shafts. When the rate of flow through the sewers is pretty uniform, the lower shafts in the district will become down-cast shafts, and those in the higher portions of the district become up-cast shafts, provided, however, that the temperature of the atmosphere is less than the temperature of the air of the sewer. If the temperature of the atmosphere is greater than that of the sewer, no currents are produced, but an interchange takes place, through these open shafts, between the atmospheric air and the air of the sewers, in accordance with the law that regulates the diffusion of gases. It should not be lost sight of, that the low shafts opening on the roadway can be made as efficient as the higher shafts at considerably less expense. The efficiency of a shaft is proportionate to the square root of its height; consequently short shafts of larger area may be made quite as effective as smaller shafts of greater altitude. For example:—A shaft terminating in the centre of a roadway where the sewer is 9 feet deep, if made three times the area of a shaft 81 feet high, would theoretically be quite as efficient; while, in practice, the low shaft would be the more efficient, as there would be less friction. Moreover, less pressure will be exercised throughout a system of sewerage where ventilation takes place, through low instead of through high shafts, and these shafts terminating at the ground line, being completely surrounded with earth (which may be looked upon as a non-conducting material), are not so liable to be affected by the variation of temperature as shafts erected in exposed positions, and therefore will preserve the efficiency of the ventilating shaft in cold weather, when an exposed shaft would be inoperative.

Special pipes or flues have been proposed for the ventilation of sewers. Such pipes are usually made of metal connected with the crown of the sewer, and secured to the external walls of houses. The objection to the use of these metallic ventilators is, that in cold weather, when the sewers have such a temperature as to produce a natural tendency to discharge their gaseous contents into the air, the vapours ascending these long metallic tubes become so chilled as to condense the aqueous portion and check the natural tendency of ventilation. In connection with house drains ventilating shafts may be used, as they will act efficiently for the purpose of air to escape when it becomes compressed, as, when any water is passed into the drain, it may be taken as a rule that every drop of water that is poured into a drain causes the displacement of an equal amount of the foul air of the sewer. In every system of sewerage, the same volume of water may be made to displace several times its volume of sewer air. Whenever ventilating shafts are used, great care should be taken with regard to the point of efflux, especially in those cases where shafts are not fitted with any apparatus containing oxidizing material. The point of exit should neither be near a window, nor a chimney, as there are, at certain periods of the year, currents of air through windows and down chimneys into houses, so that, if the point of discharge is permitted to terminate near these openings, sewer gas may be drawn into our habitations. Very great care should be exercised in forming the joints of these ventilating shafts, especially in cases where they have to pass through the interior of houses, as it must always be borne in mind that the superior temperature of a house has always a natural tendency to lead to the escape of gas within rather than without the house.

Fig. 2.



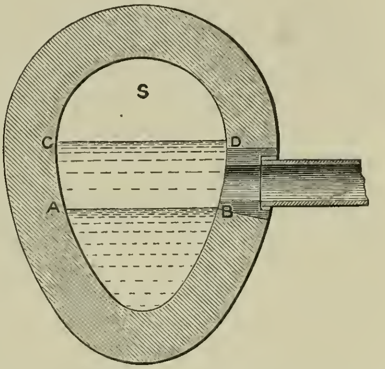
Special shafts, both with and without furnaces, have been proposed and used as experiments in connection with the ventilation of sewers. Fig. 2 shows the general arrangement adopted where shafts with furnaces have been used. Numerous experiments have been made with shafts of this description. In the report of Mr. J. W. Bazalgette, C.E., on the ventilation of sewers, addressed to the Metropolitan Board of Works in January, 1866, some results as to the efficiency and the cost of this mode of ventilation are given. Speaking of the ventilation experiments made with the Clock Tower of the Houses of Parliament, he says:—

"I found that the furnace of the Clock Tower of the Houses of Parliament was supposed to have been connected with the adjoining district, to the extent of about a quarter of a square mile, and with about 6½ miles of sewers in length, when added together; but that the ventilation had, in reality, been intercepted by a flap, so that the benefit supposed to be derived therefrom was purely imaginary. Having come to that conclusion, the next thing I directed my attention to was, supposing the whole of the air extracted by that furnace was produced from the sewers, and supposing that all the intermediate channels could be stopped, and that it could be directed from the most remote ends of each of the sewers, and distributed over those sewers with the most perfect theoretic accuracy, so as to have an uniform current passing throughout each of the sewers towards that chimney, still the effect upon those sewers would be nothing, and the way in which I prove my statements is this: the total area of the 6½ miles of sewers now connected with the furnace is 713 feet; the total area of the channel through which the air has to be brought from them is 8 feet, that is about the ninetieth part of 713; the air was passing at the rate of 542 feet per minute through the 8 feet area. Therefore, if I could divide that over the whole district, the velocity in all those sewers would be 6 feet per minute, or $\frac{1}{15}$th of a mile per hour. But we have shown already that there exist in the sewers, from other causes, velocities amounting to 100 feet per minute upwards, and 6 feet per minute is, practically speaking, stagnation, and not ventilation. Supposing you could obtain theoretic perfection, and all the air produced by this furnace was spread through this district, you would only then get up a velocity of $\frac{1}{15}$th of a mile per hour, which is no ventilation whatever. But I have gone further with the inquiry. Whilst we were making our observations on Tuesday, the furnace being kept up, was consuming at the rate of eight chaldrons of coke per day; but I will assume that the defective arrangements, that is, the chimney being stopped up the circuitous connections and so forth necessitated a very much larger consumption of fuel to produce the same effect than could be produced with better arrangements with a less quantity. I will assume that four chaldrons of coke per day, or half the quantity actually used, would produce that current of air, and that, when produced, it would effectually ventilate the 6½ miles of sewers, which I think I have shown to be impossible; but, supposing it were possible, then I find that for 1500 miles of sewers 230 such furnaces would be required, and the cost of the coke at each of those furnaces would be 876*l.* per annum, at four chaldrons per day, giving a total for the whole ventilation of the metropolitan sewers of 201,480*l.* per annum upon the consumption of coke, without any labour or incidental expenses. The prime cost of those 230 chimneys and furnaces and establishments I have put down at 2000*l.* apiece; that would give 460,000*l.*, or half a million of money."

It has been proposed to make use of the shafts in connection with the various manufactories of towns. There are many objections to the plan, the principal being on the part of the owners of the shafts. In some cases the partial ventilation of sewers, or sewage tanks, is effected by connecting these structures with the furnaces. This is done at the sewage pumping stations of the metropolis, and the operation is effected by closing the front of the ash-pit, and making a connection between the sewers and the under side of the fire-grate, so that all the air for supplying the furnaces must be taken or pass from the sewers.

Rain-water pipes, as ventilators for sewers, have been very extensively adopted. In Mr. Henry Austen's report to the Commissioners of Sewers in 1849, he strongly recommended the use of rain-water pipes, in preference to shafts or furnaces; but experience has shown that in those districts in which ventilation of the sewers has been intended to be performed by the rain-water pipes, it has been found that the system does not possess those advantages which are absolutely necessary for an efficient system of ventilation. Under certain circumstances rain-water pipes are rendered totally inefficient as ventilators, and these circumstances arise when ventilation is the most needed. Whenever ventilation is carried on by the rain-water pipes, these pipes are invariably connected with the house drains, and the house drains are connected with the sewers, and it is assumed that the rain-water pipes will serve for the ventilation of both the public sewers and the house drains. A slight amount of consideration will show that in times of heavy rainfall when the sewers are gorged with sewage, and when the rain-water pipes are doing duty in their legitimate capacity in carrying away the rainfall, this system becomes totally inefficient for the purpose of ventilation—1st, as regards the public sewers, because every junction made with a public sewer is made at such a point, that if there is a small quantity of sewage flowing through the sewer the house drain may have a free outlet, and at such times the rain-water pipes may serve as ventilators for a portion of the sewer. But the moment the sewers begin to fill in time of rain, and naturally to expel the gases which are present, the inlet of the house drain is effectually sealed with water of considerable depth; consequently the whole of the gases which have accumulated in the upper section of the sewer and above the entrance of the house drain, become compressed, and soon acquire sufficient power to force a passage for themselves, and in such a direction as least anticipated. In Fig. 3 the sealing of house drains is shown. The ordinary water-line in the sewer is shown, and also the water-line during moderate floods. The sealing, therefore, of house drains, in times of storm, shows the necessity of carrying out a system of public ventilation totally independent of the ventilation to be provided for house drains. Moreover, as has been already mentioned, the rain-water pipes during times of rainfall are doing duty in their legitimate capacity; consequently, at such times they naturally form inefficient ventilators even for the purposes of house drainage, as at such times they are completely gorged with water.

FIG. 3.



There are also other objections to the use of rain-water pipes terminating under the eaves of a house or near windows. Experience at Croydon with regard to the use of rain-water pipes for ventilation purposes is so strongly manifested as to furnish conclusive evidence of the total inefficiency of such a mode of ventilation. A reference to the mortality tables of Croydon shows that the more rigorously the system of ventilation by rain-water pipes was pursued, the more unhealthy the district became, and it was not until special means were used—at the recommendation of the author—for the ventilation of house drains, and an efficient system of ventilation for sewers carried out, that the death-rate was at all reduced. Early in 1860 the bye-laws of the Croydon Local Board of Health were approved by the Secretary of State. One of these bye-laws had reference to the ventilation of sewers by means of rain-water pipes. Previously to this the ventilation of sewers had been chiefly carried on by a number of ventilating pipes which had been erected at various points along the course of the sewers, principally at their heads. For the first year or two the bye-laws were not rigidly enforced, but so soon as they came to be enforced, we find that the rate of mortality in the district materially increased. For example, in 1860, the year in which the bye-laws for the ventilation of sewers were passed, the rate of mortality was 16·63; in 1861, 18·00; 1862, 18·48; 1863, 20·4; 1864, 20·9; 1865, 21·26; 1866, 20·04.

It should be mentioned that, in 1866, public ventilation of sewers was carried out, and has proved very satisfactory in its results.

If further testimony is needed as to the efficiency of rain-water pipes to act as ventilators, it is supplied by the evidence of Dr. Carpenter, of Croydon, and published by him in a pamphlet entitled 'Hints on House Drainage.' He says: "On inquiry I found that all the earlier fatal cases (alluding to fatal cases of typhoid fever) dated the commencement of illness from two distinct periods. Now those periods were preceded by a very heavy rainfall; on one occasion nearly 1½ inch of rain fell in the preceding 24 hours, and on the other nearly 1 inch; on each occasion the temperature was high, and there was an entire absence of ozone in the atmosphere. I do not mean to assert that each case actually commenced immediately after the rainfall, but in upwards of 20 fatal cases into the history of which I examined, the commencement curiously ran up to two distinct dates, and of many slight cases the patients stated that they had not felt well from about the same periods. To what cause could those isolated cases of fever be attributed? how had the rainfall acted? and why should it act injuriously upon a perfectly well-drained town? Unfortunately, for myself, an experiment was performed before my eyes, which enabled me distinctly to point to cause and effect. My own house is connected with one of the main sewers, and has for many years been protected by a ventilating pipe, which ascending from the soil-pipe of the closet, was made to terminate, for convenience, near a cistern of large size, outside the top of the house. On the night of October the 17th I was aroused by a loud noise proceeding from the closet; it continued at intervals throughout the next day. Unable, at first, to account for it, I eventually found that it was caused by the ventilating pipe doing duty as waste pipe to the overflowing cistern. There was no room for exit of foul air from the sewer, which, therefore, was forced through the trap of the water-closet, with, at times, the force of steam through the safety valve of a steam engine. The nuisance continued for nearly three days before the weather would allow the plumber to rectify a mistake which had been committed in the previous summer—the mistake of making the ventilating pipe do duty for a waste pipe. The escaped air did not smell offensively, a faint odour alone being recognised; it was, therefore, thoughtlessly tolerated. The excessive rainfall also prevented much ventilation of the house by open windows. Two or three days afterwards one of the occupants of a room, the farthest in the house from the closet, fell ill, with symptoms of typhoid fever, and in a few days the other person sleeping in that room also showed signs of the disease; no other person in the house suffered from it. In the room occupied by these two persons, the foul air from the closet, as proved by experiment, naturally ascended."

The lamp columns in our streets have been proposed to be used as a means of providing ventilation for our sewers. The use of the steam jet was proposed by Sir G. Gurney, in combination with properly constructed shafts for the ventilation of sewers. The action of the steam jet is due, in a measure, to the rarefaction of the air, the partial vacuum created, and to velocity of the escaping vapour, which drags along with it the sewer air Like all the other plans that have been proposed for effecting the artificial ventilation of sewers, the steam jet would affect such a limited area as to be totally inadequate to meet the requirements of the case, and, moreover, would prove both inconvenient and expensive.

The work of ventilation should be carried out so as neither to cause injury to health, nor to be of any inconvenience or nuisance to persons inhabiting the district. In order, therefore, to be successful, ventilation must be carried out in such a way as to prevent the accumulation of those gases or vapours in the sewers, which, if allowed to escape uncontrolled, are detrimental to human life, and are a constant source of annoyance and danger to those who carry out their avocations within the sewers. It should also be borne in mind that a system of ventilation, to be perfect, should embrace not only the expulsion of the foul gas from the sewers, but also the supply of a sufficient quantity of pure atmospheric air. Measures should be taken by breaking up the sewers, so as to prevent the undue accumulation of gas in the highest portions of the district, or of its transference from the low to the higher districts. Figs. 4 and 5 demonstrate the principle involved in the system. Fig. 4 represents a branch sewer, discharging into the main outfall sewer at A. This branch sewer may be of indefinite length, and is drawn with one uninterrupted fall; therefore the gases generated will naturally ascend towards B, or, at other times, when the gases within the sewer become compressed, by reason of the increase in the flow of the sewage, they will be forced to the higher portions of the district. Under some circumstances, a ventilator may be placed at A, and another at B, the air would enter at A, and rush up the sewer to B, with a velocity determinable by the altitude of B above A; and, even supposing that there is an opening midway between the two points, or at C, the gases moving from A, in the direction of B, having a given velocity, are moving in the same plane as the line of sewer, therefore will leap over the ordinary space of the manhole at C, so that the gas has a tendency to accumulate in the neighbourhood of B. To remedy this defect, and prevent the undue accumulation, or transfer of gas, the sewers are broken up

Fig. 4.

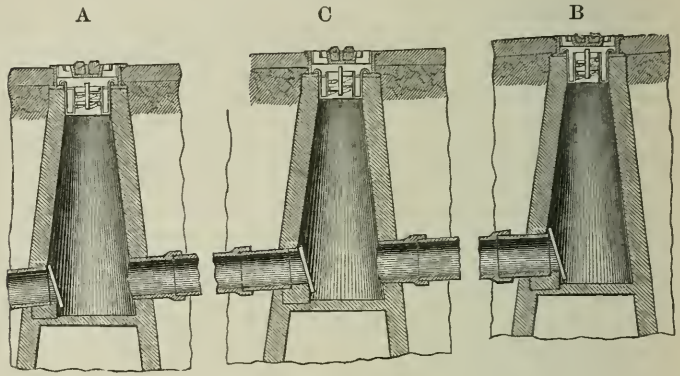
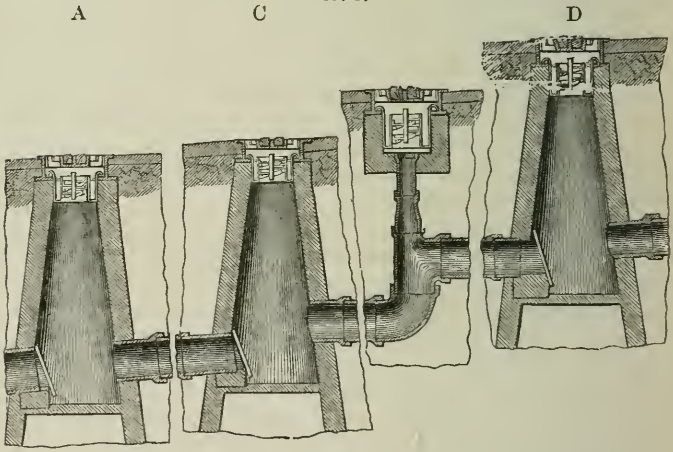


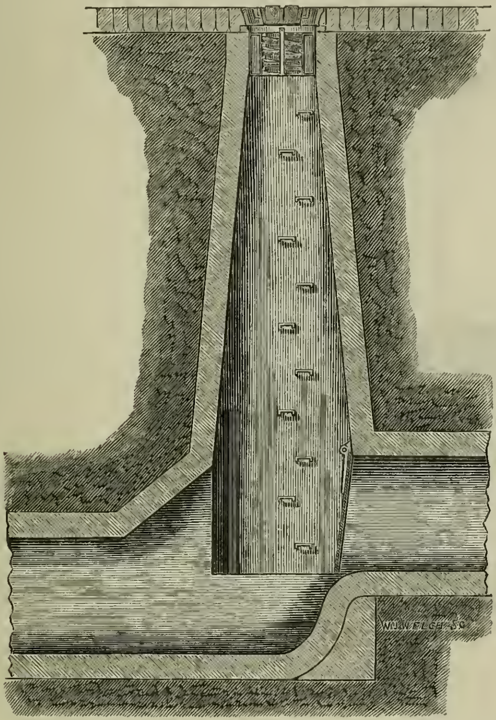
Fig. 5.



into a series of steps, as shown in Fig. 5. The gases, therefore, that are found at A, or between A and C, have a tendency to be discharged at C, because the sewer above C is not in the same plane as the sewer below C, and the gases are consequently directed out of the line of plane in which they were travelling, and are necessarily compelled to escape at C, and as every manhole becomes a shaft for drawing off the foul gas, the comparatively short distance the manholes are asunder tends to make the whole system work very efficiently.

Other provisions are also made; for instance, the introduction of lightly-balanced hanging valves, which fill the upper portion of the sewer, to prevent a direct current of air from the lower to the upper districts. This arrangement is shown in Fig. 6.

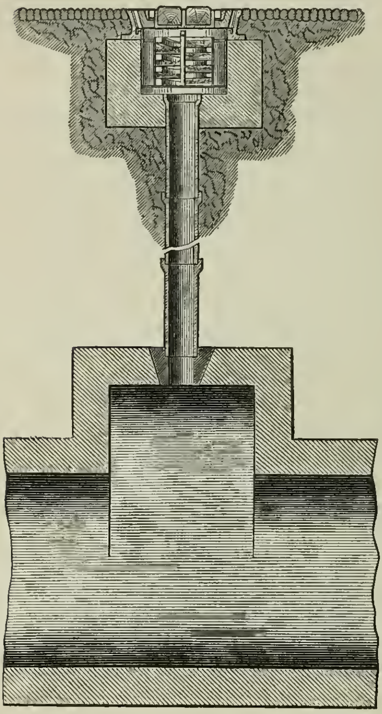
FIG. 6.



In sewers of flat inclination, the author has introduced chambers, in which gas may be allowed to accumulate and discharge through a shaft placed in the upper part of the chamber, as shown in Fig. 7. This arrangement is equivalent to the breaking up of the sewer, as shown in Fig. 5. It should also be borne in mind that in every system of sewers the house drains should be ventilated, for reasons that have already been pointed out, when speaking of the connection of house drains and sewers.

A system of oxidation, or absorption of the sewer gases, carried on in combination with the street ventilators, is for all practical purposes the most efficient and least expensive plan that can be adopted. Just as noxious portions of liquid sewage are absorbed by land, so the obnoxious qualities, or the aerial impurities in the vapours that escape from sewers, may be absorbed by highly absorptive materials, so as to secure their removal, and prevent any evil consequences arising. Various plans have been suggested for absorbing or destroying sewer gases, but, in the experience of the author, that system which embraces, not only the abstraction of the noxious qualities of the gas or vapour of sewers, but also destroys them, is the safest and best in practice.

Fig. 7.



Various modes have been proposed and adopted for absorbing or destroying the noxious property of sewer air. It is well known to chemists that all porous substances have, more or less, the power of condensing gases within their pores. Charcoal, as an absorber of sewer gas, is probably the most efficient, and the cheapest agent that has been used for the purpose of absorbing or destroying the noxious property of sewer air. Professor Muspratt says:—"The absorbing powers of charcoal are so great that some have doubted whether it is really a disinfectant. This opinion has probably arisen from imperfect views of its *modus operandi*, since it not only imbibes and destroys all offensive emanations, and oxidizes many of the products of decomposition, but there is scarcely a reasonable ground of doubt remaining that it does really possess the property of a true disinfectant, acting by destroying those lethal compounds upon which infection depends." A piece of charcoal placed in a volume of sewer gas will absorb that gas. It is not necessary for the gas to be mechanically brought into contact with the material, but, just as the loadstone attracts iron, so charcoal attracts the noxious ingredients of sewer air. Dr. Voelcker says of charcoal: "It possesses the power not only of absorbing certain smelling gases—sulphuretted hydrogen and ammonia—

but also of destroying the gases thus absorbed. For otherwise its purifying action would soon be greatly impaired. It is very porous, and its pores are filled with condensed oxygen to the extent of eight times its bulk. We have, therefore, in charcoal, oxygen gas (which supports combustion or lights fires) in a condensed and more active condition than in the common air which we breathe. Hence it is that organic matter in contact with charcoal is so rapidly destroyed. The beauty of charcoal is that the destruction takes place imperceptibly, and that its power of burning organic matter is continually renewed by the surrounding atmosphere, so that it is a constant carrier of atmospheric oxygen in a condensed state in its pores. The oxygen that acts on organic matter, and burns it up, is speedily replaced, and the process goes on continually. Hence it is that a comparatively small quantity of wood, or peat charcoal, is capable of destroying a very large quantity of organic matter."

The absorption of gas by different varieties of charcoal is given in the following Table compiled by Dr. Stenhouse:—Half a gramme of charcoal absorbed the following quantities in centimètres:—

Kind of Charcoal.	Ammonia.	Hydrochloric Acid.	Sulphate of Hydrogen.	Carbonic Acid.	Oxygen.	Sulphurous Acid.
Wood	98·5	45·0	30·0	14·0	0·8	32·5
Peat	96·0	60·0	28·5	10·0	0·6	27·5
Animal Charcoal ..	43·5	..	9·0	5·0	0·5	17·5

Liebig says, in his Letters on Chemistry that, one cubic inch of beechwood charcoal contains pores equal in area to 100 superficial feet. As to the efficiency of charcoal for ventilators, Dr. Stenhouse says, "The efficiency of the charcoal appears never to diminish, if it is kept dry, and its pores are not choked up by dust. The only precautions to be observed are, that while the filters shall be sheltered from rain and moisture, free access shall be given to the air." He also says, with regard to the construction of filters, "I should prefer using two or more thin filters placed at short distances, say two inches from each other. These thin filters disinfect the air quite as efficiently as a single thick one." Dr. Letheby recommends charcoal air-filters as being "the cheapest and best, as well as the most effective plan for dealing with noxious exhalations from sewers." From what has been stated it is clear that charcoal kept dry is probably the most efficient material for purifying sewer air, as it is not only a disinfectant, but it destroys or burns up the noxious gases. Some doubts may arise as to its use in connection with sewer ventilators, on account of the escaping vapours being highly charged with moisture; therefore, on this point it is requisite for us to be assured that the moisture taken from sewer air aids rather than impairs the efficiency of charcoal. From a paper "On the Absorption of Mixed Vapours by Charcoal," read before the Chemical Society on the 20th January, 1870, by J. Hunter, Esq., M.A., the results of experiments with charcoal and moist vapours are given, which are extremely interesting and useful. The results of these experiments show, that if charcoal is introduced into a mixed vapour, the vapour "which is nearest to its point of condensation is first absorbed, and this, in its condensed state in the pores of the charcoal, aids the absorption of the other vapour. According to this view a succession of condensations is going on. The theory is strikingly illustrated in experiments with a mixture of water vapour and ammonia gas (obtained by heating an aqueous solution of ammonia of specific gravity 0·88), when the mixture is much more largely absorbed than either the gas or vapour separately. The mean of a set of experiments made at 100 deg. and a mean pressure 706·2 mm. was 316·6 volumes of the mixture absorbed by one volume of charcoal." Dr. A. W. Williamson, the President of the Chemical Society, remarked on the results shown in this paper, that they were entirely in accordance with what was expected on theoretical grounds. These experiments confirm the faith in charcoal, for they prove that the vapour of water, when near the point of condensation, instead of being prejudicial, greatly assists the absorbing power of the charcoal.

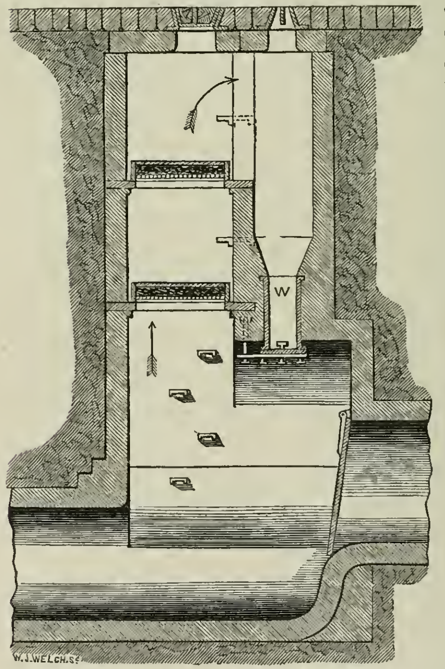
Lime has been used and repeatedly recommended for use, as an agent for neutralizing or purifying the gases escaping from sewers. Chlorine gas has also been proposed as a means of dealing with the gases which escape at the ventilators provided for the sewers. Various modes have been suggested for liberating these gases by the use of common salt and nitric acid, or by placing materials rich in chlorine, such as chloride of lime in trays, and from which the chlorine would slowly pass into the surrounding air. Sulphurous acid has been proposed in connection with the deodorization or oxidation of sewer air, and at the present time experiments are being made with it by the Metropolitan Board of Works.

With regard to the action of sulphurous acid gas, in the words of Dr. Angus Smith, "It first deoxidizes, but gives off its oxygen easily, and acts as an oxidizer. It also acts as an acid and dissolves animal matter. Its action is complex; it causes coughing, and it is, in great quantities, injurious to the lungs, but how much in small quantities is not known. It purifies the air from putrid matter, destroying that when in a state of vapour, as it destroys putrid and living bodies dissolved, or in a liquid state, and it is therefore an excellent fumigator. How much it brings of other evils is an important question. It alters the air of towns entirely; every coal-burning town is compelled to breathe it." This gas, if present in excess when escaping from the ventilator, would be very disagreeable to many persons on account of its sulphurous smell, and when gas is used at those periods of the day when there are in-currents into the sewer, the diffusion of a large quantity of sulphurous acid gas, or of chlorine, would be attended with great inconvenience to the men who may be engaged within the sewers. There are great difficulties in applying the proper quantity of acid to manufacture gas for the destruction of gas. The gas manufactured itself becomes an impurity when present in excess, and, if not present in sufficient quantity, the sewer gas would not have its poisonous properties destroyed. Sulphurous acid gas or other gases have not at present been shown to be such efficient agents as charcoal, when properly applied, and moreover they are attended with considerably greater cost. Other materials have been proposed to be used in connection with the abstraction and destruction of gas; such, for example, as carbide of iron—a material which has been extensively used in the filtration and purification of water, and of which Mr. Spencer (its inventor) says it is an extremely useful and durable material for the purpose of absorbing and destroying foul gases, and for the purification of air generally. It was proposed by him to a Committee of the Houses of Parliament as the means of removing the unpleasant odours from the air supplied to the Houses of Parliament, when the Thames was in a filthy state, and rendered the atmosphere pestiferous.

Many forms of ventilation have from time to time been used, with such arrangements for containing charcoal, or other absorbing material, as the knowledge of the day rendered necessary or convenient. It should be observed that, with the knowledge we now possess in designing a ventilator in which charcoal or other absorbing material is to be used, the placing of the charcoal in mass, so as to entirely fill the aperture of the ventilator, goes to a great extent to interfere with the free escape of the air at such times as it is being expelled from the sewers, or at other times being drawn into the sewers. We know from experience what is the effect on our chimneys if we inadvertently leave in them bundles of straw or shavings, which are quite as porous as charcoal in mass. Just then, as all draught is stopped by these porous substances when placed in the house flue, so charcoal placed in a mass will interfere with and check the proper ventilation of our sewers. Wherever, therefore, charcoal is used in a mass, the vapour on the sewer side of the charcoal will at times have a considerably higher degree of tension than that on the street side, because a certain power must be exercised in expelling the vapour through the mass of charcoal. A perfect ventilator, therefore, should combine the means by which no force is required to be brought to bear to expel the gases from the sewer, for as soon as an uncontrolled force is brought to bear, there may be times when the accumulation of gas within the sewers may be attended with great inconvenience. Another point in the construction of ventilators which is of vital importance is the means that should be adopted in getting rid of the surface and rainfall water, which will enter the opening provided for ventilation.

From what has already been stated, it is clear that charcoal, so long as it has to contend only with the ordinary vapour of water, will retain its efficiency for a long period, but the moment it becomes completely saturated with water, the oxygen is driven from its pores, and ceases to absorb or destroy noxious gases of sewers. Wherever ventilators are placed in the centre of streets, these streets having more or less a fall longitudinally, so that in time of rain the ventilator often becomes the receptacle for the water flowing from a very large area, as the water flowing down hill, especially in macadamized roads, following the ruts made by carriage wheels, if not allowed to escape into the sewers, soon fills the receptacle provided for it, and then flows over and destroys the charcoal. It has been proposed to prevent the water entering the ventilators by raising them above the general level of the road; but this plan is attended with inconvenience, and only partially meets the difficulty. Many attempts have

Fig. 8.



been made to get rid of this water without injuring the charcoal, but such attempts have not been very successful, the channel provided for the escape of the water also allowing the escape of the sewer air. In the ventilators which have been used by Mr. Rawlinson (shown in Fig. 8), in one case trays are placed to fill the aperture in the manhole, and in another (Fig. 9) they are placed vertically. The introduction of trays of charcoal into manholes is objectionable, the charcoal being placed in mass, interferes with the natural ventilation; moreover, as these trays cannot be made to fit tightly round the manhole, sewer gases pass away by the sides without being brought into contact with the materials used for their destruction. They are also attended with much labour in renewing the material, or removing the trays from the manhole, when men require to enter. An objection to charcoal being placed vertically, is that unless jammed in its position so tightly as to stop ventilation, in course of time it settles down, leaving an aperture over it, by which the gases may escape without coming into contact with the charcoal. The use of a single vertical tray will also allow gas to escape at the sides, as it is a matter of impossibility to render them air-tight. In the ventilator (Fig. 9) provision has been made for getting rid of the water by collecting it in chambers, or by allowing it to pass through a filtering medium to the sewers. The author's own experience of this filtering arrangement is, that in course of time it becomes choked. In times of rainfall, and in districts in which the inclination is great, a large amount of rainfall is passed into the receptacle, which does not flow away, but overflows and wets the charcoal. In other cases the channel provided for the escape

Fig. 9.

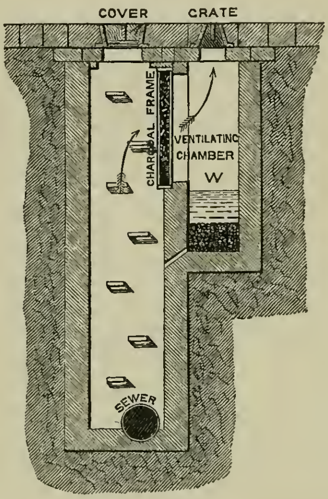
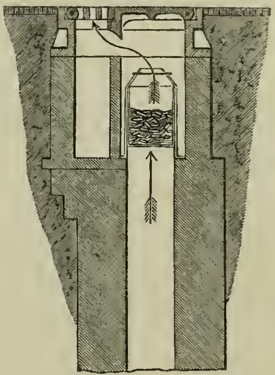


Fig. 10.



of the water also allows the escape of the foul air. Fig. 10 shows an arrangement adopted by the Metropolitan Board of Works for experimental purposes. A single tray containing charcoal is placed over a vertical pipe, leading directly from the crown of the sewer. The charcoal in this case is also placed in mass, and no provision is made for getting rid of surface water. Figs. 11, 12, show an arrangement adopted in the metropolitan districts.

Fig. 11.

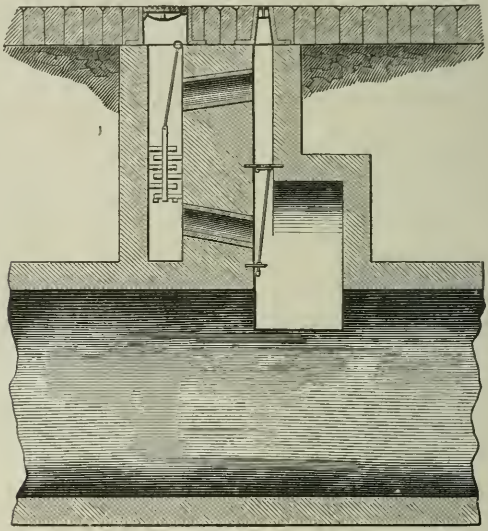
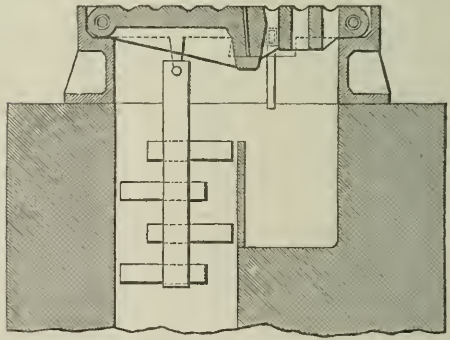


Fig. 12.



The trays do not fill the aperture, but are laid zigzag, so that there is an open space through the ventilator. This arrangement is good, as an aperture is left communicating with the atmosphere on one side, and with the sewer on the other, the charcoal being placed on trays in such a position that the gas must come into contact with the trays, while no pressure can be exercised in expelling the gases from the sewers. The fault of this system is that the ventilating trays cannot be made to fit tightly at the sides, therefore a small amount of gas can escape by the sides of the trays into the air. The dirt-box, moreover, is so small that in times of heavy rainfall it is quite inadequate, and gets filled up, and the water flowing over destroys the charcoal. Having used these ventilators very extensively, and finding that in heavy rainfall the charcoal invariably got destroyed, the author determined to introduce an improvement upon them, which consisted in making an arrangement by which the rainfall can be passed away in such a manner as not to destroy the charcoal, and at the same time prevent the escape of the gas, without coming into contact with the charcoal. This ventilator is shown in Figs. 13, 14, and 15. An improvement on this ventilator is shown in Figs. 16, 17 and 18, which consists of, 1st, the frame for receiving the cover, on the bottom of which hangs the dirt-box and charcoal ventilator; 2nd, the cover, the centre part of which is solid, so as to form an efficient protection for the charcoal. The grating, by which air can escape from or enter the sewer, is arranged concentrically round the outer periphery of the cover, and any dirt or water entering the open grating falls at once into the dirt-box immediately below; 3rd, the dirt-box, which hangs in a groove made in the lower part of the frame. This box is circular in plan, and the groove in the frame, which receives it, should be filled with fine sand, when the weight of the dirt-box

FIG. 13.

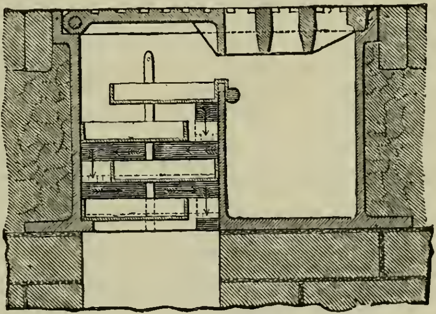
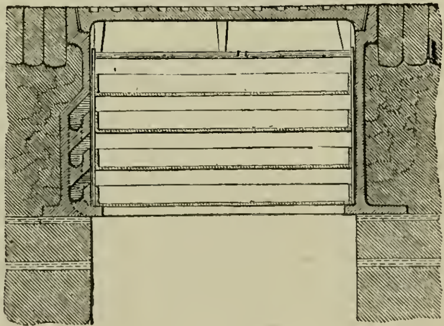


FIG. 14.



and ventilator pressing into the sand forms a gas-tight joint. In the centre of this dirt-box is arranged a spiral trough, open at

Fig. 15.

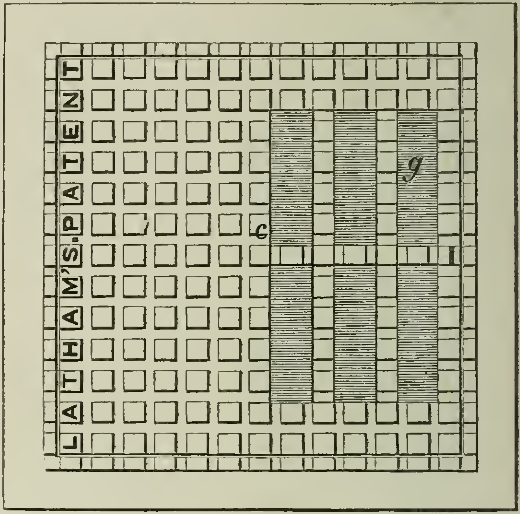
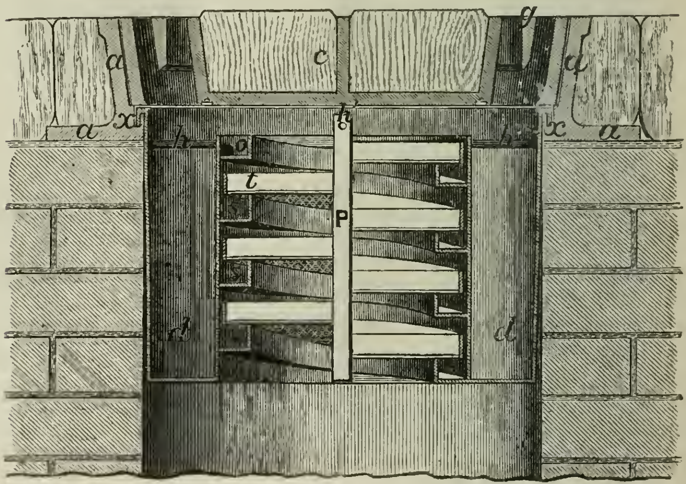


Fig. 16.



the top and communicating with the top of the dirt-box, and is used for conveying away the overflow water from the dirt-box and transmitting it to the sewer; 4th, the spiral trays for containing the charcoal are arranged round a central shaft, and divided into compartments so as to prevent the charcoal from sliding down to the bottom of the ventilator, and are screwed into the ventilator over the open spiral trough. The advantages of this ventilator are:—1st, if the charcoal concretes on the trays, or its pores get filled with dust drawn in from the street, no impediment is offered to ventilation, as in this ventilator there is a free communication between the sewer and the external atmosphere; 2nd, that the charcoal is protected from rain or water leaking through the joints of the cover or falling through the open gratings; consequently it will retain its efficiency for a long period; 3rd, the passage provided for the overflow water from the dirt-box is not dependent upon traps or any mechanical device to keep it in order, while at the same time the escaping gases cannot possibly pass by the sides of the tray, or in any other way without being brought into contact with

Fig. 17.

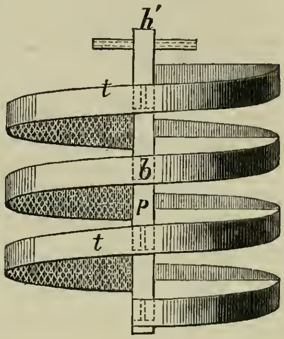
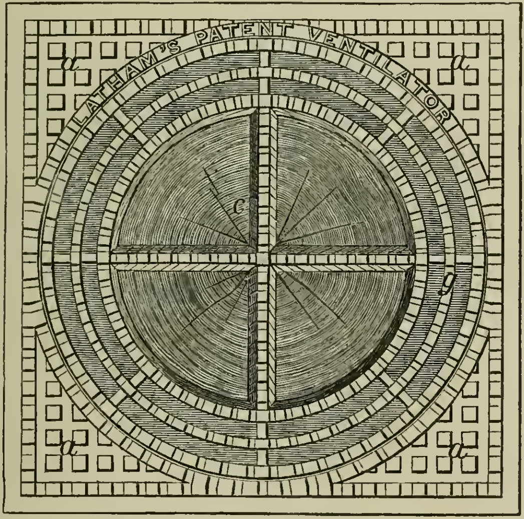


Fig. 18.



the charcoal. In the engravings *c* is the manhole cover, *d* the dirt-box, *s* the spiral trough, *t* the spiral trays containing the oxidizing material, *o* the overflow from dirt-box into trough, *g* the open grating for escape of oxidized gases, *h* handle for lifting out dirt-box, h^1 handle of spiral trays, *x* the sand-trap forming a gas-tight joint.

The action of this ventilator may be explained as follows:—The dirt-box being placed in position, and the spiral tray having been filled with wood charcoal, broken the size of filbert nuts, and screwed into the dirt-box, and the cover being placed in position, any mud or dirt passing through the open grating will fall directly into the dirt-box, and any water entering at the open grating would first fill the dirt-box, but when it had risen as high as the slot communicating with the upper portion of the spiral trough, it would overflow by this channel passing under the trays of charcoal to the sewer. The gases ascending from the sewer in obedience to well-known laws have always a constant tendency to ascend, and as the charcoal of the spiral tray is laid at a considerable angle to the direction of the escaping gases, these gases impinge upon the charcoal at every point of the ascent. Any gases ascending by the spiral trough, provided for conveying away the overflow water, are brought into contact with the charcoal just as if they ascended by any other part of the apparatus.

In this ventilator, if the trays do not fit tightly at the sides, no escape of gas will arise, as the trough for conveying away the outflow water projects into the ventilator, and any gases escaping by the side of the tray will be thrown against the projecting trough above, and so into the mass of charcoal. The circular form of the passage through the ventilators, moreover, causes the gases to move by a series of deflections, all of which tend to bring it more intimately into contact with the charcoal, and the trays for containing the charcoal are perforated; consequently, there is nothing to interfere with the ready absorption of the gas by the charcoal. The larger size of these ventilators combines a manhole cover, lamphole, and ventilator, for, by removing the cover, and withdrawing the charcoal, it forms a lamphole, and by further withdrawing the dirt-box it becomes a manhole. The arrangement that each part is separately movable has its advantages, as the charcoal and dirt cannot get mixed. The dirt-box can be speedily emptied, by removing and capsizing it. The apparatus is easily fixed, and is economical in cost, as a much smaller amount of brickwork is required when it is used in connection with a manhole than is required in some other forms of ventilator. These ventilators are also constructed to be applied in connection with ventilating pipes of house drains, for it should be understood that, except in cases where charcoal is used at the top of a ventilating pipe, water is formed by the condensation of the vapour ascending the pipes in cold weather, and which, trickling down the sides of the pipe, will destroy the charcoal; but in this ventilator a spiral trough carries away the condensed water to the sewer.

FIG. 19.

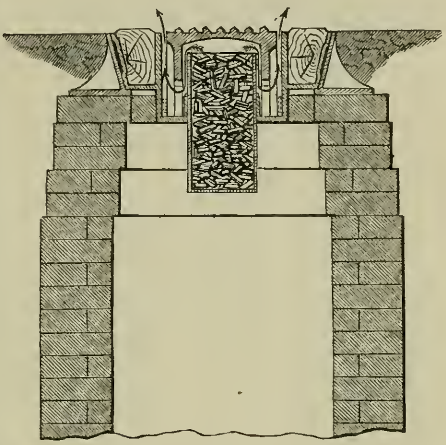


Fig. 19 illustrates Mr. A. Jacob's patent ventilator. This ventilator has many points of recommendation, but it has also its defects. When used in combination with a manhole, the provision made for the reception of dirt or water is very small, while no provision has been made for conveying away the rainfall, or surface water, which will naturally fall into the open ventilator, and speedily fill it. Consequently, in times of heavy rainfall, if the cylinder which contains the charcoal fits tightly, the rainfall will pass over into the charcoal and destroy it, and if the joints are not tight the gases will escape at the joints, and pass away without coming into contact with the materials employed for their destruction. Fig. 20 is an illustration of Harrison's patent ventilator. It is similar to those introduced by Mr. Rawlinson, having a vertical tray. The objections that have been already made against these trays render it unnecessary again to refer to them. This form of ventilator differs from the ventilators which have been referred to, as it combines movable dirt-box, and an overflow for the rainfall and surface water. This overflow consists of a pipe, which dips into the sewage, at the bottom of the manhole, so that there is always an area of sewage equal to the superficial contents of the pipe open to the atmosphere.

The ventilation of house drains is also equally important with that of public sewers. From the observations that have been already made, with reference to the sealing of house drains in periods when the sewers are gorged with sewage, every house drain, unless ventilated, becomes as it were a hermetically sealed chamber, and every drop of water compresses the atmosphere, until it gains a sufficient force to find an exit. And the points of exit are usually the weakest traps, which are generally found in the interior of a house. House drains, under such circumstances, will of necessity ventilate themselves into the houses of the district. Attempts have been made to ventilate house drains in the direction of the flow of the sewage. For example, Mr. Lovegrove and Mr. Jennings patented an apparatus, combining a trap with a separate passage for the escape of sewage air (Fig. 21), as such traps would be placed at the lowest of the house drains, to which point the sewage would naturally gravitate. But air, by the same law, when taking its natural course, would move in an opposite direction, so that a system opposed to the natural order of things cannot be commended. It is true, as the inventors say, that they can get a current of air in the direction they provide, but air only takes that direction when forced, as in the case where there is no other point of escape, and every connection is hermetically sealed; the water entering the house-drain increases the pressure within the drain to such an extent that it will force a passage into the sewer, but the air would never naturally take that direction. In

Fig. 20.

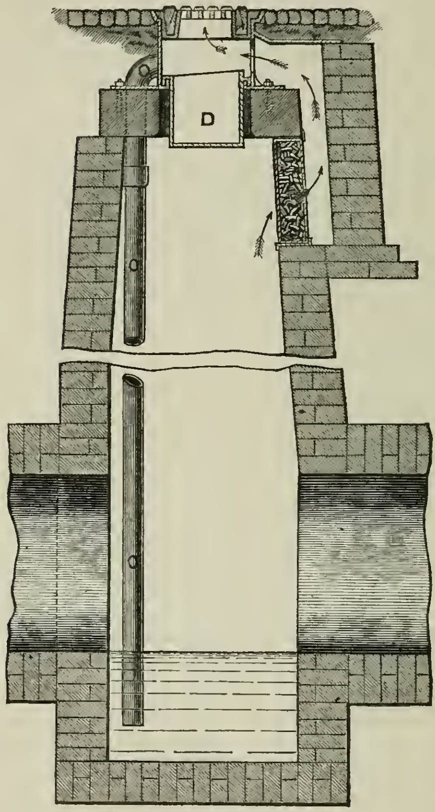
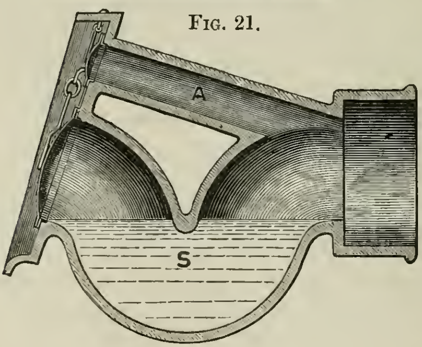


Fig. 21.



the experience of the author the best way of ventilating house drains is the true Roman style of carrying up the ends of the drain to some convenient point, and leaving the exit open. Care must be taken as to the point where these ventilating pipes should terminate, the same observations applying to them as have been made with reference to ventilating shafts in connection with sewers. In some cases it may be advisable to use charcoal. Fig. 22 shows an arrangement proposed for the City of London,

FIG. 22.

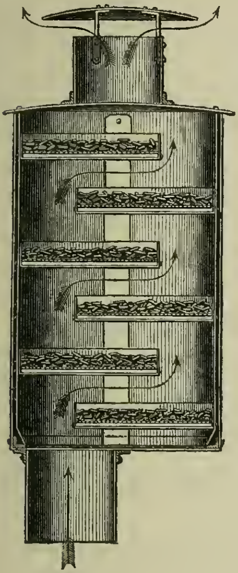


FIG. 23.

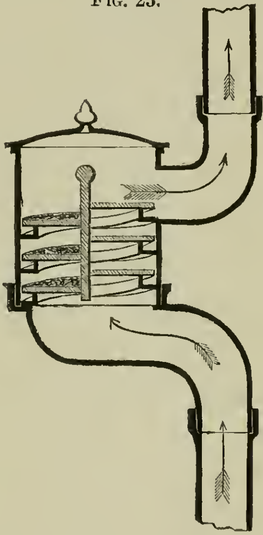


FIG. 24.

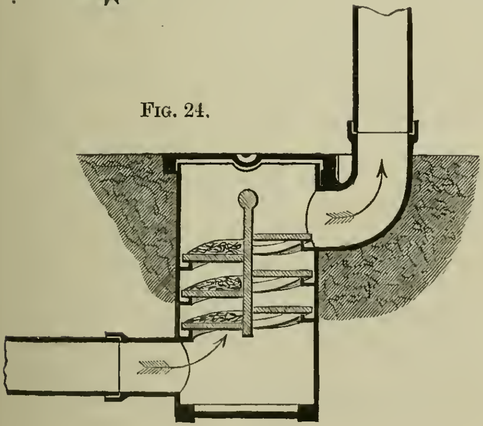
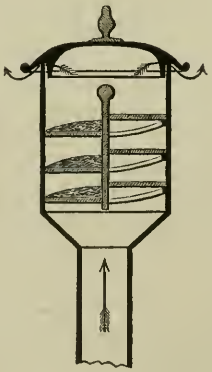


FIG. 25.



for the purpose of applying charcoal to some of the ventilating shafts which have been erected. This form is only applicable to the upper end of the ventilating pipes. Figs. 23, 24, and 25 illustrate the arrangement in which patent ventilators are used in combination with shaft or house drains. It should be borne in mind that if charcoal is used in these ventilators it should be capable of easy access, and in the example of the City sewers, Fig. 22, the ventilator is only applicable to the summit of the pipe, therefore difficult of access. The arrangement shown in Fig. 24 is applicable to any part of the pipe. In the use of charcoal in ventilating shafts, except in cases where it is placed at the top of the pipe, the sewer air contains a large amount of the vapour of water, which condenses in the cold sides of the pipe, and would fall down and destroy the oxidizing materials. But in the arrangement shown, Fig. 24, the charcoal is applied in such a way that the condensed vapour may pass away at once to the sewers without damaging the charcoal. With regard to the results that have arisen where the ventilation of sewers has been adopted, the case of London affords a striking example. Here the sewers are ventilated, yet no general plan is adopted for dealing with the noxious effluvium from them.

And yet London stands at the head of all large towns by reason of its small death-rate, showing the success of the sanitary works executed therein, and that they are of a more perfect character than those of any other place. This comparatively small death-rate in London, as an established fact, has been ascribed by more than one eminent authority to the somewhat rude ventilation provided for the sewers. The case of Croydon shows clearly that the proper ventilation of sewers has been attended with very marked results. The history of the sanitary works of Croydon, their successes and failures, is of great interest to the sanitary world.

In 1849 the Public Health Act was adopted in Croydon, and in 1850 the works of sewerage were commenced. These works were not completed until 1852. As has been before stated, after the completion of the works the district became seriously affected with diseases, which have since been traced to a connection with the escape of sewer air. A reference to the mortality shows that shortly after the completion of the works, when it would naturally be concluded that the rate of mortality ought to have declined, it considerably increased, and that increase went on, until some crude provision for ventilation was made, which served the purpose of that day. But no sooner did the population begin to increase, and the sewers to be more severely tested, than the rate of mortality also increased.

It may be said that Croydon, being sewered on the small-pipe system, the result of non-ventilation was attended with more serious consequences than would be the case were the sewers of large size, as the fluctuation in the rate of flow has more marked effects in increasing the pressure of the imprisoned sewer air in the small sewers. After the outbreak of the disease, when the district was provided with crude means of ventilation and when these sewers were only occasionally used, the rate of mortality was low; but so soon as the sewers came to be largely used, and being small in size in proportion to the volume of sewage they had to convey, the forces at work within them led to the discharge of sewer gas into the houses of the district. Therefore, as the district increased in population, disease and death also increased. Another period is very marked in the ventilation of the sewers of Croydon, *viz.* when rain-water pipes were used for the purpose of ventilation. In 1860 the bye-laws before mentioned were passed by the Home Secretary, giving the power of using rain-water pipes for ventilation. It may be stated, in passing, that no sooner did the bye-laws begin to be enforced than mortality increased in a corresponding ratio, until, in 1865, there was a mortality of 21·26. In 1866 measures were introduced for ventilating the sewers totally independent of rain-water pipes, or special shafts communicating with drains or sewers, for the ventilation of the public sewers. The consequence has been that, during the last four years, since the introduction of this new system of ventilation, the average rate of mortality, in Croydon, has been 17·47; whereas in the previous four years the average rate of mortality was 20·6, and during the last eight years the population has nearly doubled.

It is well known to those conversant with sanitary matters, that it is difficult to maintain the standard of health in a district in which the population is increasing. Yet, in the case of Croydon, owing in a great measure to the efficient steps taken for the proper ventilation of sewers, the rate of mortality has declined, until it has already reached a point unparalleled in the history of sanitary science, in a district having so great a population.

At the close of the paper the author made some experiments illustrative of the effect of charcoal in checking the passage of air through a ventilator, and also of the effect of the expansion of the air in an unventilated sewer in drawing out the water from a drain-trap.

DISCUSSION.

Mr. HOUGHTON said that the paper was a most valuable one, although he could not agree with the author as to the down-cast and up-cast shafts. In his experience, which extended over many years, he never met with a ventilator that was a down-cast shaft. He always found it in every case an up-cast. Again, as to the trapping of the drains, he (Mr. Houghton) believed that a drain properly trapped could not be served in the way the author's experiment showed. Engineers took great pains in having the sewers laid out well and scientifically; but the execution of the most important part—that was the house drainage—was entrusted to men thoroughly unfit for the work. It was generally done by the piece at a ridiculously low price, and was, consequently, scamped in every way; and although thousands of pounds might be expended in a good system of drainage outside the houses, the benefit might be counteracted or lost by defective execution of the drainage inside the houses. The mortality table exhibited did not speak much in favour of the sanitary measures and drainage carried out at Croydon since 1850. He saw the mortality was about 18. After all the works that had been carried out, there appeared to be, in the year 1870, very little improvement, at which result he was very much surprised.

May 1*st*, 1871.

BALDWIN LATHAM, President, in the Chair.

THE VENTILATION OF SEWERS.

ADJOURNED DISCUSSION.

Mr. Slack said he did not approve of the charcoal system. It appeared to him that the charcoal would cause an obstruction in the ventilator.

Mr. Arthur Jacob said he presumed that Mr. Slack did not doubt the efficacy of charcoal, but that his ground of objection was, that charcoal occasioned an obstruction in the ventilating shaft, and prevented the escape of those gases for which the ventilating shaft was actually provided. Of course, in that view of the matter, everything would depend upon the arrangement of the charcoal. There was an opinion that if charcoal was arranged in a mass it was very objectionable. That depended upon what amount of charcoal would cause an obstruction. A very considerable quantity — more than was necessary—would probably prevent the free escape of the air.

The principle to be kept in view was, that there should be equalized barometrical pressure between the sewer and the outer atmosphere. If that was done there was nothing to fear, as there would be no tendency to break through the traps, and no tendency of the sewer-air to enter houses. If such a tendency was removed a very perfect system of ventilation would result. He (Mr. Jacob) had advocated the ventilation of sewers by street openings, and as far as the present legislation enabled them to ventilate sewers, he believed street openings must be resorted to as a means of getting rid of the foul air, because there was no provision, as far as he was aware, to enable local authorities to compel householders to fix ventilators. Although he had designed a ventilator for street openings, he still held that such ventilators would be unnecessary if efficient ventilation could be effected by means of house ventilators; that was to say, if every water-closet and sink was ventilated, he believed no further ventilation would be required. The application of charcoal to ventilators was, of course, quite practicable, and was a very simple matter. By the ventilators shown in the diagrams the sewer air was delivered in a purified condition above the roofs of the houses, out of all contact with the lungs of the inmates, and was discharged into such a volume of atmospheric air, that the diffusion took place very rapidly, and the health of the inhabitants could in no way be affected. According to Mr. Latham's theory, there were animal organisms which made their way into the air in spite of charcoal and everything else, and which organisms came into contact with the lungs of the human beings. Hence it was of the greatest importance that ventilators should be carried up above the houses. The street ventilators represented in the diagrams were of various forms, some of which were better than others. As regarded his (Mr. Jacob's) ventilator, he thought the author of the paper had laboured under a mistake, as he had represented his ventilator as being faulty.

Theoretically, it was faulty, but, practically, it was not. In a modification of his ventilator, the chamber for the dirt-box was considerably enlarged. The casting was carried up round the cylinder, and the cylinder, with its flanges, rested upon the edge of the casting, on an india-rubber band, making the contact perfect; so that no sewer air could possibly escape between the casting and the cylinder. It might be said, possibly, that the dirt-box was not of sufficient size. His answer to that was, that, arranged as the ventilators were at the crown of the road, a very small quantity of water got into them. The facility for removing the dirt-box and the dirt was very great, and experience had shown him that there was very little to be desired. The rain which fell into the openings was provided for by four siphon openings, so that it could only fall about five or six inches, which he thought would be quite sufficient for all the evaporation which would take place in the summer months, and if it was found that evaporation took place, so as to leave those holes exposed and allow the air to escape, then nothing would be easier than to let the water-cart stand there for a few moments, and the ventilator would be perfectly safe. Of all the forms proposed, undoubtedly that which offered the greatest facility for changing the charcoal and removing the grit, and at the same time examining the sewer, was the best street ventilator. An objection had been raised to the principle of ventilating pipes carried above the houses. It was said that in very cold weather, when the air inside the sewer was warmed and charged with moisture, condensation took place, and, in addition to that, the air, in escaping, was very much cooled, and became specifically heavier, and that would to some extent obstruct the escape of the air from the sewer. Doubtless, however, the elastic forces communicated to the air in the sewer by a large accession of storm water, or the daily fluctuation which took place in sewers, would more than counterbalance that increase in the specific gravity in the upper part of the sewer.

Mr. Shields said he had been informed by the Engineer of the Metropolitan Board of Works that he had tested the efficiency of charcoal upon a large scale, and had come to the conclusion that charcoal should be avoided, as it became practically useless in a very short time, and he had therefore decided not to adopt it. If, however, those were the views of the Board of Works as to the means of ventilation, their ventilators were practically useless, and their number insufficient for the perfect ventilation of the sewers. He knew that, upon complaints being made of the smells arising, the Board had stopped many of their street ventilators. Instead of doing that, and so increasing the discharge of foul air from those remaining, they should rather have opened additional ventilators, and so lessened the amount of foul air discharged at any one spot. His impression was, that a small quantity of foul air discharged into the centre of a street was not very prejudicial to the health of the population of a large town, and London itself was a practical proof of that assertion. There was one point in the paper upon which he differed from the author, and that was with regard to the construction of the sewer ventilator. The point was one upon which the author laid a great stress, and was that of a sewer not having a continuous bend throughout. Now his impression was, that what the author said would be perfectly correct, provided the sewer could be constructed so that the plane would be broken in an effectual manner, and the ventilator so placed that the gas would be intercepted. It was needless to say that that could not be the case in practice for very obvious reasons, and he should prefer that the sewer should be continuous, giving a continuous flow for the sewage, and that the foul air should be allowed to escape simply by means of an ample opening. He did not think that the column of air moving upward in the sewer had a sufficient velocity to carry it into the upper part of the sewer, but, on the contrary, he thought that the column of air moving with a low velocity and being extremely light, followed its natural bent, and ascended directly it had the opportunity of so doing. He thought that the sewer would be better if carried continuously through, than if carried through upon a higher level. And, moreover, he did not see any occasion to interfere with the flushing apparatus, because the flushing door could be made to fit a sewer just as accurately as anything else.

Mr. Houghton said that if sewers were properly constructed, they required very little ventilation. In the case of Croydon, it was stated by the author that the original drainage of Croydon to a great extent failed through the sewers being too small. Knowing, however, that Mr. Ranger laid down the sewers on the most scientific principles, he (Mr. Houghton) could not agree with the author's conclusions. He believed the sewers in Croydon would have proved quite large enough if they had been constructed according to the designs. Pipe sewers, when properly laid, required no ventilation except at the top. They would keep themselves perfectly clear, much more so than brick sewers. The epidemic referred to as having taken place in 1853 could hardly be traced to the sewers, or to the want of ventilation. He believed it arose more from the fact that people were unaccustomed to water-closets in their own houses. Previously the outside privies were exposed to the influence of the atmosphere, and had not that baneful effect upon the health of the inhabitants which an indoor closet, badly attended to, badly supplied with water, and generally neglected, would produce. The defect in Dr. Carpenter's house was not owing to defective ventilation, but to the bad workmanship of a plumber who constructed a waste-pipe as an overflow from a cistern on a wrong principle. He (Mr. Houghton) considered that charcoal ventilators did more harm than good to the ventilation of the sewer. In the course of a short time they got stopped up, and there was no ventilation in the sewer when required, whereas pipe sewers did not require ventilation. From the mortality table at Croydon, he thought that town was in a very unsatisfactory state. As compared with many places where the system of drainage was very imperfect, it did not stand very high. There was no ventilation at Portsmouth, and yet the mortality during last year had been wonderfully low, much lower than at Croydon, according to the table. Taking the Registrar-General's Quarterly Report and Returns, there were many places with the same number of inhabitants, or a greater population per acre, giving a much better result than Croydon did; therefore he could not think that the ventilation spoken of so highly had improved the health of the place.

He had tried ventilation with house drains, and the system had answered comparatively well. He had also tried ventilation in tall chimneys, such as the dockyard chimneys, two or three hundred feet high, and the result was very faulty. The effect in the sewer was very imperceptible at a small distance from the outlet. As to down-cast and up-cast shafts, he had never met with any sewer having a down-cast shaft.

Mr. Macgeorge said he could not assent to the opinion that the ventilation of sewers was unnecessary. He believed it was a question of the most vital importance in a sanitary point of view. Sewers contained a considerable quantity of gas, and in opening a junction of sewers, it was found that it had a considerable pressure when it was not ventilated, and that in itself was sufficient proof that ventilation was necessary, as the gas under pressure would necessarily escape at the weakest point. Unless that weak point was given to it by a ventilating shaft, or some other similar means, the gas would pass through the closets, and enter the houses, and be most mischievous. With respect to what had been said about Portsmouth, he did not know that they could put much reliance upon the report. If Portsmouth had been tried both with and without ventilation, and had the results been given, a correct judgment might be arrived at. But Portsmouth might have special advantages which would nullify any comparison with Croydon, or any other place. The ventilation of sewers was a matter for careful scientific investigation, and he thought that at the present time very little was really known about it. Attention was, however, being directed to it, and no doubt in time a plan would be devised which would be satisfactory and sufficient for the purpose of securing that which was necessary for the public health. The President, Mr. Jacob, and many others had introduced several ingenious contrivances for the purpose of ventilating sewers. He (Mr. Macgeorge) did not think that it was a settled question yet as to which was the best method of ventilating, but he thought that street ventilation, and breaking up of the gases as much as possible, were the best means that offered at present. He had tried large shafts, and they produced very little vacuum in a sewer. He had paid some attention to the amount of vacuum produced in a shaft from 100 to 200 feet high, and he had never found more than $\frac{7}{8}$th water pressure given in a shaft 200 feet high. That had but little effect when the number of openings was taken into consideration, because, to obtain a good vacuum, all admission of air must be excluded. The very fact that air was admitted at various points tended to destroy the vacuum which was produced by admitting a current of air at a higher temperature. He thought that Croydon, whatever might be said about it, was a very strong instance of the good effect of ventilation; he did not know a stronger one. It might be that the sewers were too small, or it might be that they were not; but, at any rate, it was a fact that, when the sewers were ventilated, an effect of the most beneficial character was produced, and he thought that, notwithstanding all the theories that might be introduced, and all the hypotheses that might be suggested, nothing could guide engineers so well as the facts which they could gather, and there were facts in the paper which were of very great value. With regard to charcoal, he had his doubts about its use. Charcoal in a dry state was very useful, and it was undoubtedly a powerful deodorizer; but it was subject to so many variations in consequence of the dampness of the atmosphere, or steam in the sewers, or defective drainage in the ventilators, that it became damp, and met with a variety of casualties. Hence the charcoal, which was very useful in a dry state, became useless when wet. With regard to the question whether charcoal was the best substance to be used in ventilation, he was not satisfied that it was, and he thought that a satisfactory conclusion had not been arrived at as to the best mode of ventilating sewers.

Mr. Colyer said that near his works a great nuisance was created by a sewer ventilator which was fixed in the pavement. The cover was left open for the purpose of ventilation, and the sewer gases entered the houses, and at times rendered them unfit to live in. He thought it was quite possible to ventilate the sewers without such a nuisance as that, simply by placing the ventilators in the middle of the road. Mr. Houghton mentioned that pipe sewers did not require any ventilation. He (Mr. Colyer) would like to know the reason why.

Mr. Houghton said that the simple reason was that, if they were properly constructed, they were perfect in themselves, and decomposition could not take place in them. It was a matter of impossibility, in a pipe sewer properly made and properly proportioned to its work, for decomposition to occur. But in brick sewers, with a limited supply of water, as in the case of London at the present time, in dry weather decomposition occurred very largely; and it was only in the case of heavy rains that the sewers got properly cleaned out. He did not mean to say that brick sewers should not be used in certain cases, but he was of opinion that pipe sewers were far better for the duties they had to perform—such sewers, for instance, as were laid down in Croydon in 1849 and 1853.

Mr. Colyer said at Dartford, in Kent, pipe sewers were a perfect failure. He believed Woolwich was drained by Mr. Ranger upon that plan; and he understood that was also a failure. He thought Mr. Jacob recommended that sewers should be ventilated by the householders, and would be glad to learn what kind of ventilator Mr. Jacob would recommend.

Mr. Jacob said it was usual, in well-organized towns, to carry pipes from the house drains. Some arrangement of that kind was generally insisted on; but it was a recent provision, and had not been fully carried out. The plan he should recommend would be that of carrying a metal pipe, outside the house, up to a sufficient height above the roof to clear the windows, and at the same time not to be sufficiently near the chimneys to cause the risk of a down-draught.

Mr. ARTHUR RIGG said that ventilation was certainly necessary; and the Metropolitan Board of Works acknowledged that fact by using ventilators in the streets. Persons who had once been over those ventilators, however, would take care never to pass over them again if they could help it, because of the stench that issued from them. They were opened occasionally; and the ventilation thus effected, however good, was not sufficient. It appeared that Mr. Latham's plan consisted of absorbing the gases, and deodorizing them before they escaped into the atmosphere. The use of charcoal, whether it was perfectly efficient or not, was good, because there was no substance that absorbed the gases so well as charcoal did. Dr. Voelcker said charcoal possessed the power not only of absorbing certain gases, sulphuretted hydrogen and ammonia, but also of destroying the gases thus absorbed. There was a considerable difference of opinion amongst chemists as to what the action of charcoal was; but it seemed to him (Mr. Rigg) that it was not a chemical question at all. Charcoal was very porous, so long as it was dry; but when it was damp the pores were full, and then of course it did not act as a deodorizer. The action of the oxygen of the air on the sewage gases which went into the charcoal was much the same as in the lungs of animals. A short time since he examined a section of the human lungs by a microscope, and he found it to be full of cells about a thousandth part of an inch in diameter. The cells were full of passages, and the walls were about the two thousandth part of an inch. The air was mixed with the blood, and exactly the same production of carbonic acid took place there as in the pores of the charcoal—at least, that was his opinion. There were other substances in which a similar action took place. For instance, in the case of spongy platinum, where a jet of hydrogen was directed against it, the mixture of the oxygen of the air which it had absorbed with the hydrogen gas caused immediate combustion, and, in fact, chemical action seemed to be created between those substances. Chemical bodies, such as oxygen and others, were endued with the power of combining with other substances. The oxygen had the power of combining with many other gases, if only they were close neighbours. If arsenic and antimony filings were dropped into chlorine, they would take fire and combine. Dutch metal, which was used for gold-leaf, was another instance of this action. The state of division affected or increased the energy of combination. There was another instance, something analogous to the charcoal system, in the case of Moule's earth-closets. So long as the earth was dry, the same action took place as with the charcoal in Mr. Latham's ventilators. He would ask if dry earth had been tried for Mr. Latham's ventilators. Of course, it was not so efficacious as charcoal; but it might be better than nothing at all. The action of chlorine had been alluded to. Dr. Odling described chlorine as acting simply as an oxidizer, and nothing more. There was another thing which occurred to him in connection with the ventilators described by the author. With regard to the Liverpool ventilator, he would observe that it was a very usual thing to see them spinning at the tops of houses; and they looked most industrious. But if their action was analyzed they would be found to do no good at all, but rather the reverse. In order to make the matter clear, he would assume one of them to be upon a 2-ft. shaft; and he would assume the pitch of the screw to be 1 ft. Now, the draught of the chimney he had measured under three circumstances. In an ordinary chimney, without a fire, with the doors shut, the draught was 162 ft. per minute. With the door open, it was 188 ft. With a moderate fire burning, the draught was 250 ft. per minute. That was about two or three miles an hour, and the pressure corresponding would be ·02 and ·44 to the square foot. The revolving caps showed the velocity of the wind, and the velocity with which the caps moved was exactly one-third of the velocity of the wind, because of the difference between the concave and convex sides of the cup. Supposing a gale was blowing at the rate of 1800 ft. a minute, the velocity of the circumference of the apparatus would be one-third—that was, 600 ft. a minute; and, with a 6-ft. circumference, that would be 100 revolutions per minute. Of course, it appeared to move excessively fast, because there were so many vanes; but, with a screw of 1 ft. pitch, it would not be more than three-quarters of that, and 75 was therefore the speed with which a screw would suck a current of air up a shaft like the one shown. It was mentioned in the paper, that Mr. Bazalgette had measured the velocity of the current in the ventilating chimney of the Houses of Parliament, and that it was 542 ft. per minute. If such a gale as he (Mr. Rigg) had mentioned would only drive a screw at 75 ft., it was evident that an ordinary light gale might not suck up more than 10 ft. a minute; and, of course, that action was perfectly useless. All that was wanted in a ventilator of that kind, was to prevent the current blowing down; because, if the current was slightly warmed, it would find its way out without the contrivance at the top. The current would drive the ventilator, instead of its helping the current; therefore it seemed to him that it would act better if the top screw were taken out; and he should put on the top of the chimney that which might be seen on many chimneys, and which answered very well—that was, a small truncated cone of smaller area, increasing to about the diameter of the shaft below. That answered very well on chimneys in preventing down-draught, and it appeared to him that it would act as well for a ventilator.

Mr. A. Williams said that Mr. Houghton had stated that in pipe sewers, if properly laid, there was no necessity for ventilation. If there was any outlet at all—which, of course, there was—there must be ventilation. But, even then, he (Mr. Williams) did not see why a pipe sewer should be more perfect than a brick sewer, if the brick sewer was set in Portland cement. A little moisture would, perhaps, get through the brick, but very little indeed; and he could not see why a brick sewer should be worse than a pipe one, or require more ventilation, or retain more foul gas. It was not the sewer that made the foul gas, because, whether a sewer was made of pipe or of 4½-in. or 9-in. brickwork, the same amount of foul matter went into it; and, if a pipe of the same size as the brick sewer was used, there would be the same amount of foul matter. Of course, a 6-in. pipe drain must not be compared with a 3-ft. brick sewer. They must both be taken as of the same capacity. He could not see any difference in them. Mr. Houghton had also stated that he had never heard of a down-cast shaft to a sewer. Well, he (Mr. Williams) thought there were a number of down-cast shafts. For Mr. Houghton had admitted that there were a great many water-closets incapable of doing their duty; and if a water-closet was not perfect, there must be a down-cast shaft. One of the great faults of closets was their not being properly attended to; but he (Mr. Williams) did not know how a sewer was to be cleansed from foul gas unless there was a down-cast shaft.

The President said with regard to Mr. Slack's objection to charcoal, he (the President) thought that objection was very similar to his own, *viz.* that when charcoal was placed in a certain position so as to obstruct the free ventilation of the sewer, it was objectionable. Moreover, when it was in such a position as to be liable to rapid destruction, it was objectionable. The opinion of the meeting appeared to be that it was advisable to use some material for the absorption of the various noxious gases. Whether that material should be charcoal, or some other substance of a more durable nature, was not a settled point. He had made experiments with other substances, such as carbide of iron and oxide of iron, which he had some faith in as extremely durable materials for the purpose of the absorption of sewer gases, especially carbide of iron. With regard to the principle that Mr. Jacob had advanced, *viz.* that if every house drain was perfectly ventilated it would be unnecessary to ventilate the public sewers, he (the President) would take the case of half a million of houses within the metropolitan area, the whole of which were connected at the present time with sewers, and if every house drain was ventilated, that would not ensure at times ventilation of the public sewers, for the reasons that he had laid down in his paper. The connection of every house drain with the public sewers was made at such a point as that when the sewer was running at its ordinary level the house drain had a free outlet into the sewer; but so soon as the sewer began to fill in time of storm, the house drain itself became trapped by reason of the water having risen about its mouth, and in large sewers it might rise some feet above the mouth of the house drain. Consequently, when the water rose in a sewer of that description, the space between the water-line and the crown of the sewer contained the gases under pressure, and if there was not a point of escape under control, they would seek a point which was not under control, and probably that point might be some weak part connected with the system of house drainage, or of the sewer itself. Therefore it was absolutely necessary, not only to provide ventilation to the house drain, but also to every public sewer. Each sewer should have its own system, and that totally independent of the system of ventilation in the house drainage. He agreed with the remarks made by Mr. Shields, as to the ventilators of the Metropolitan Board of Works; in fact, where a smell proceeded from a ventilator, it was a sure sign of want of ventilation, and instead of stopping ventilators, they ought to be increased in number to a very great extent. The early sewer works at Croydon were so constructed that they had only some half-dozen ventilators for the whole system of sewerage of the place, and those few emitted such offensive odours that, by a special order of the Board, they were stopped up. Then began all the train of evils which had been referred to in the paper as arising from the want of ventilation of the sewers.

Referring to Mr. Houghton's remarks as to pipe sewers not requiring ventilating, the President said he thought that pipe sewers were liable to the same vicissitudes and subject to the same conditions as others. The same laws and rules affected them as affected brick sewers. Every house drain, as a rule, was a pipe sewer, and ventilation was required there, and equally so in every public sewer which was constructed of pipes. Referring to the gases which had to be dealt with, he observed that there was first an organic vapour which was given off from the moment fæcal matter was discharged into the pan of the water-closet.

Until it was utilized or dissipated it was giving off organic vapours. Those vapours changed in their character, because allied to them they had other vapours, that was, gases—but the organic vapours were totally distinct from the gases—sulphuretted hydrogen, ammonia, and so on. The fæcal matter and the liquid flowed together down the sewer, and the air, being constantly brought into contact with it, became corrupted. The process was the same in a pipe as in a brick sewer, and it was equally necessary that ventilation should take place, because pipe sewers were liable to a greater extent to those degrees of fluctuation which gave force to the air of sewers. Consequently, in his (the President's) opinion, founded on practical experience, pipe sewers really required more ventilation than brick sewers did, because in a large sewer of oval section, when there was a small quantity of water and the fluctuation in the flow was small in proportion to the whole pressure of the sewer, the fluctuation was comparatively slight. But with the same quantity of water running in a pipe sewer, the pressure was so great that its influences were far more material than those in a larger sewer.

With regard to the mortality tables of Croydon, the diagram showed the death-rate in 1848, when they began their works. The works were then carried on to 1853, at which time they had completed them and stopped up the ventilators. In that year the mortality reached to 28·57. Seven years before the application of the Public Health Act to Croydon, the rate of mortality was twenty-four in a thousand, the average during the last ten years had been a trifle over eighteen, and in that time the district had increased in population from about 16,000 to nearly 70,000. Mr. Houghton had mentioned a number of towns, or rather had suggested that there were a number of towns, where the mortality was as low. But there was not one town having a population of 60,000, or even 30,000, where in the last ten years they had had so low a mortality as eighteen in a thousand. Mr. Houghton, in referring to the direction of currents and the flow of air in sewers, had stated that down-cast shafts were never made; that in-currents in the sewers were things that had never been known within his experience. But they had been known within the experience of those who had had every opportunity of observing the facts. He (the President) had a report of Mr. Bazalgette and Dr. Miller upon the ventilation of sewers in London, and which was dated 19th December, 1866. The first passage was:—

"It was found that the direction of the draught and its amount were liable to be interfered with by local accidents, such as imperfect closure of the trap, the variable forces of the wind, and the opening and shutting of a side entrance, so that the act of entering or leaving a sewer for the purpose of experiment was more than once found to reverse the direction of the current of air in the body of the sewer during the observations."

That showed how extremely liable that was to take place, especially at particular points, as in a sewer which was upon the point of turn between its maximum and minimum flow, when it was at an uniform volume and there was no great disturbance of the forces at work, such as high internal temperature of the sewer and low external temperature. Under such circumstances as those the slightest thing would change the direction of the current, either in or out of a sewer—either up or down; because, if there was a current up the sewer at the lower point of entrance, there was a current in the sewer, and so at the higher point there would be a current out. With regard to the experiments mentioned in the Report, it stated that—

"In the first series of these experiments, made on the 23rd of May, the current of air was up the sewer in a direction contrary to the flow of the water. The time which the smoke occupied in passing from the point of firing to that of the observer on the watch, was 45 to 121 seconds, the average velocity being 66 seconds or 4254 feet per hour. On the following day, the 24th May, charcoal was placed in the ventilating boxes. After it had been in use a week, the experiments were repeated at the same part of the sewer. On this occasion the draught was down the sewer, or in the same direction with the flow of water. The time it was running down at that period averaged 86 seconds, or 3263 feet per hour."

The fluctuation at particular times might have been entirely due to the time at which the observations were made, because if observations were made when a sewer was rapidly filling during the period of the maximum flow of the sewage into the sewer, then there was invariably a current out of the sewer; but if the observations were made at the time when the flow of the sewage was rapidly declining, then there was an in-current into the sewer. On the 7th of June another series of experiments was made. The current of air was down the sewer, or in the same direction as the flow of water. The observations on the 6th of November were taken on rather a windy day, and the direction of the current fluctuated. With regard to the fluctuation, he (the President) had found, on a windy day, that the wind blowing on the top of the ventilator had a remarkable effect on the direction of the currents of air. The observations on the metropolitan sewers entirely established the fact that there were currents at different times in different directions, and that those currents were due to the forces which were at work in the sewers themselves.

Mr. Shields had drawn attention to the fact that many eminent authorities who studied the question had looked upon ventilation of the London sewers as of the first importance, and as being that which had added so greatly to the success of the system of sewerage that had been carried out. With regard to those towns which were supposed to have no ventilation in their sewers—Portsmouth, for example—he (the President) thought that Mr. Houghton was rather mistaken, as he (the President) had certainly seen ventilators in the Portsmouth sewers, in going over those works some few years ago; so that Portsmouth, with its modern system of drainage, had a system of ventilation similar to that which was employed in London. Mr. Colyer had cited several cases in which works for sewage had failed. There were, no doubt, a great number of cases of works for sewerage in this country where the full benefit was not reaped, the failure, however, being entirely due to the fact that ventilation was not carried out. There were periods when in those towns the rate of mortality was reduced to the lowest ebb, and there were other times when epidemic disease was rife. At some seasons of the year the localities were never free from a disease of a certain type, and that type was one which was always produced by sewer air—such as typhoid fever. It was generally admitted by medical men that the spreading, if not the origin, of typhoid fever in a town was due to matters which arose from the sewers.

Mr. Rigg had made some observations upon the Liverpool ventilator. That was a mechanical contrivance which was intended to be continually drawing out a volume of air from the sewers. In every system of sewers there were in-currents and out-currents. It was just as important to have pure air to dilute the air of the sewers as it was to have impure air expelled from the sewers. Therefore a system which was continually exhausting from every point—supposing it was mechanically correct—would be inoperative, because it would be exhausting at periods against a vacuum,—that was, when there was a rapid decline in the flow of the sewage, and when the heavier matter of sewage or water was displaced, and its place taken by air. At such a time there was a current into the sewers which no power of the small wind ventilators would suffice to stop. The power they had at such times was rather to retard the passage of pure air into the sewers to dilute the gaseous compounds which were present, and therefore any system which did not accommodate itself to the fluctuating power at work within the sewer was imperfect. Mr. Rigg had also gone into the most abstruse calculations to show what a very small effect was produced by that kind of ventilator, even taking a very much larger one than was really used, as the shafts of those ventilators were not more than 6 inches in diameter, and many of them were 60 or 70 feet high, the material used being very thin galvanized iron or zinc—a material which was liable to certain vicissitudes of temperature, which itself would counteract the effect of the ventilators. It was quite true with regard to those ventilators, that so long as there was a pressure within the sewer to expel—that was, when the flow of sewage which would otherwise have condensed the air accumulated in the upper part—at such times they acted as safety valves, but as ventilating shafts for the purpose for which they were intended—as a means of drawing out from the sewer when there was no natural ventilation, or when there was no flow of matter into the sewer, and the temperature was uniform with the external temperature—at such times a mechanical ventilator had no effect upon the sewers. At the last meeting he (the President) made some very simple experiments to show the effect which charcoal in a mass had in impeding ventilation, and also the necessity of ventilation with regard to house-traps. In further illustration of the subject, he produced a small bottle, in the neck of which was inserted a 2-inch trap. That was a trap four times as great as that which was very often used for the purpose of trapping house drains, and which was called a bell-trap. If a sewer was unventilated, it was in the position of the bottle; that was to say, there was an inlet into it, and the outlet was sealed, as it would be, supposing that in the time of storm the level of the water in the sewer rose so as to completely seal it. If at such a time hot water, or water at a higher temperature than the air in the sewer, was to be poured into the sewer, the effect upon the sewer air would be to dilate it, and the degree of dilation would be so great as to force the whole of the traps; and as there would be the least pressure within the house, the gases would naturally escape inside rather than outside the house. [The experiment performed on the last occasion to illustrate this fact was repeated.]

The President observed that that illustrated the absolute necessity for ventilation that there must be with every system of house drainage and every system of public sewers. Unless ventilation was provided, the gases which might carry the germs of disease escaped into the house. Of course, in an unventilated system of sewers, if a particular epidemic disease was rife in a district and all the houses were connected with the sewers, when the sewers began to work under pressure, the gases which had arisen in one house in which the disease was prevalent might escape into another house and convey thither the germs of the disease. As a matter of fact, he would mention that in a town in Kent, during the last twelve months, he had clearly traced to connection with the sewers the spread of disease in a row of houses in which there had been no communication whatever between the inmates. There was a row of houses, forty or fifty in number, connected with a common drain and one common cesspool, with no ventilation, and there was a case of disease in one of the lower houses, and in every one of those houses above that there were cases of the same disease within a very short period. The authorities thoroughly investigated the point, and, on making a large number of experiments, it was found, by putting in operation the water-closets or the drains, that through every one of the sinks of those houses there was an out-current of air. This clearly established the fact that from that one common cesspool, which received the fæcal matter of a large number of people who were suffering from disease, the gases escaped and passed into each one of those houses in which the disease broke out. The houses which were drained separately—which had separate cesspools—entirely escaped from the disease, though in close proximity. That showed conclusively that in that one case the disease could be transmitted by imperfect sewers, or sewers that were unventilated. It was therefore far better to revert to the old privy system, than to have an imperfect system of sewerage. In fact, unventilated sewers were as dangerous as steam boilers without safety valves. The success of every system of drainage depended upon the perfection of the work, and no work was perfect unless it allowed for the exit of all foul matter, whether liquid, solid, or gaseous, and therefore as, on the one hand, it was necessary to have an outfall for the disposal of sewage, which gravitated naturally to the lowest point, it was, on the other hand, equally necessary to have outfalls for that gaseous impurity which had a tendency to find its way upwards.

June 5th, 1871.

BALDWIN LATHAM, PRESIDENT, IN THE CHAIR.

THE TIMBERING OF TRENCHES AND TUNNELS APPLICABLE TO RAILWAY AND SEWERAGE WORKS.*

By CHARLES TURNER.

Timber is required, in constructing sewerage works, to support the sides of the narrow and deep cuttings required in building the drainage, culverts and pipe drains for centering, drainage purposes, and other special purposes hereafter mentioned. It is also required in tunnelling, to support the sides of the shafts and the roofs and side walls of the headings to carry the tramways, and for the construction of the long pump-rods in the deep shafts. Also for centering draining trunks, and other special purposes.

The manner of framing and introducing the timber depends greatly, in the first place, upon whether the timbering is to be only temporary, that is to say, merely to support the ground in advance of the masonry, or whether, as in the case of headings for a tunnel, it is required to stand possibly for several years. It depends, secondly, on the description and quality of the timber to be used, *i.e.* whether the timber is to be round, half-round, or squared timber; and what sort of timber, and what sizes of it are available. It is usual for temporary work, such as that first mentioned, to use the timber that is the cheapest, the most easily and most economically transported, and which is the most saleable after it has served the temporary purpose required of it.

If the timber is sufficiently good and strong for its work, no objection can be taken to such a course; but it is often a very short-sighted policy, as I hope to show presently. Before entering more particularly into a description of the timbering required for open cuttings for sewerage works, and for drift-ways, headings, &c., for railway tunnels, it will be well to set forth a few simple rules for carrying out such works of timbering generally. They are well known by all mining engineers, and most of them by any good practical miner.

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* The premium of ten guineas offered by the President, Mr. Baldwin Latham, for the best Paper on this subject was awarded by the Council of the Society to Mr. Turner, of Southampton, for this Paper, which was sent in under the signature of "END GRAIN."

1st. All timber used should be of as hard and tough a nature as it is possible to procure for a reasonable cost.

2nd. All timber should be cut at the fall of the year, when the sap is drawn; and no timber ought to be used that has not had a certain amount of seasoning, having been kept either constantly wet or dry for not less than six months after it was felled.

3rd. All timber used should have been barked three months before using.

4th. The best description of timber for shores, sills, posts, &c., is larch or fir; oak may be used occasionally to resist a great transverse strain.

5th. The principal strain should in all cases be thrown as far as possible upon the end grain of the timber, or in the case of waling pieces, sills, or sleepers, which should always if possible be of half-round timber upon the rounded side of the timber.

6th. All side pillars or side posts should be set slightly oblique, forming with the head and ground sills the section of a truncated pyramid. The tenons of the pillars, &c., should be cut square, and the mortises in the sills at an angle to prevent lateral movement.

7th. The timbers should be framed and fitted accurately. No spikes or bolts to be used to keep the timbers together; all wedging up to be avoided as far as possible, except in certain cases described hereafter.

8th. All poling boards in headings and the linings at the back of the curbs, where square shafts are timber-lined, should be pointed and driven obliquely, each set to overlap the preceding one.

9th. All shores to be fitted to drive from above; and never in any case sideways or horizontally. When half-round timber is used for the waling the ends of the shores to be slightly bird's-mouthed, to fit to the shape of the timber.

10th. As large a bearing surface as possible to be allowed where the end of one timber takes a bearing upon the face of another timber.

11th. When planks, battens, or other square timber are used for waling pieces, they should be bedded in the sides of the excavation at a slight angle, so that when the shore, cut to the proper angle, is driven down from above, it will always take a fair bearing over the whole of its surface.

12th. Adjustable gauges to be provided for taking the exact length and exact angle of the ends of the timber required.

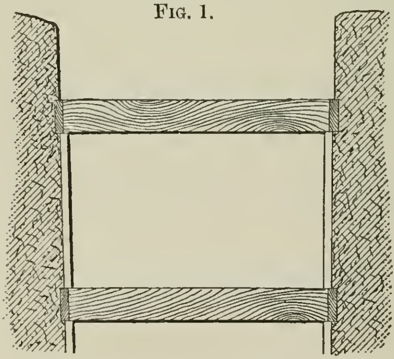
13th. No timbers require to be fitted in their places more tightly than to take a fair bearing. If any strain is thrown upon them, they will be tightened far better and more in the direction required than by any artificial means that can possibly be used.

Timber in Open Cuttings or for Sewerage Work.

Most of these works are executed either in large towns or in the neighbourhood of them, and the timber used to support the sides of the excavations is either such as can be found in the place or can be most easily conveyed to it; fir scaffold-poles cut up into lengths being used for the shores, and the cheapest description of battens, or planks, that can be procured for the walings. In many cases these are only used for form's sake, and might readily be dispensed with.

The common practice is to introduce tiers of battens, about 4 or 5 feet apart in depth, with round poles of from 4 to 6 inches diameter for shores. These are almost always driven sideways into their places, and, even if well cut and fitted, have but a comparatively small bearing upon the batten which forms the waling piece. If the cutting is dry, these shores frequently become loose and drop down, as there is seldom any upright or support under them. In many cases this arrangement proves sufficient, as no timbering is really wanted; but when there is really a pressure exerted against the timber, the waling planks or battens are very apt to split, from the shores being driven in sideways, and therefore bearing on a very small surface of the timber. If battens are used in the above manner, it is much better to cut the excavation to a slight batten, and to let the battens or planks in parallel to the face, and to drive down the shores from above sufficiently tight to give the batten a firm bearing against the sides of the excavation, as shown in Fig. 1.

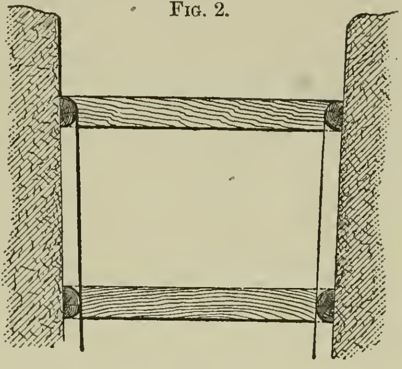
Fig. 1.



The lower tier of battens should be strutted up from the ground, and uprights should be placed at intervals between the tiers of battens, especially under the joints. Where half-round timber can be procured it is generally preferable to the battens, as it has less tendency to split.

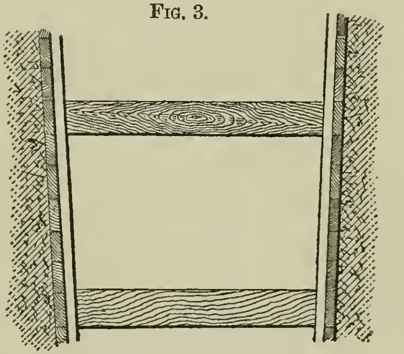
In that case the flat side of the timber should be placed against the side of the cutting and slightly let into it, and the end of the shores should be slightly bird's-mouthed out to fit the round side of the timber, and should be driven down from above, as in Fig. 2.

FIG. 2.



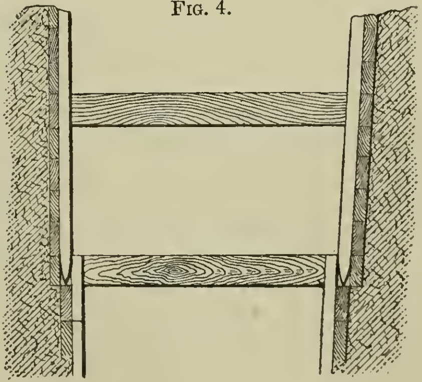
If the ground worked through is of very shifting matter, such as thin strata of sand or clay with water, it is often necessary to close-timber the cutting. In this case planks should be placed upright at intervals of from 5 to 6 feet, with horizontal planks behind them one upon the other; the usual round shores being introduced between the planks, which must always be laid at a slight angle, so that by driving down the shores from above the whole will be wedged firmly into its position. This mode of timbering is shown in Fig. 3.

FIG. 3.



Where the ground is very insecure, the upright planks can only be driven in short lengths, the one being made to overlap the other, as shown in Fig. 4, temporary shores and struts being used in some cases until the permanent shores can be driven. Where the ground is of the nature of running sand, and can only be excavated in very shallow lifts or stages, the excavation

FIG. 4.



may be carried on after the manner in which square shafts are sunk and timbered in some of the German Brown Coal Mines: upright pieces of half-round timber, pointed at the ends, being first driven into the ground in advance of the excavation, and inclining slightly inwards, waling planks are fixed between these timbers and supported in a temporary manner by short piles, until the shores are introduced and driven from above as before mentioned, care being taken always to have uprights under the joints of the waling planks. A space varying in width from 2 to 3 inches will be left behind the waling planks, into which should be driven planks or battens, or half-round pieces of timber pointed at the ends, and which pieces must be gradually driven downwards as the work proceeds, as far as safety will allow, when another upright is driven down in front of the first, in the same manner as already described and shown in sinking short lifts through shifting ground requiring to be close timbered. Great additional strength is given to this mode of timbering by introducing long binders, *a*, *a*, of stronger timber from top to bottom of the excavation, taking a bearing against all the walings, and having independent shores between them. This mode of timbering is fully shown in Figs. 5, 6, and 7.

Fig. 5.

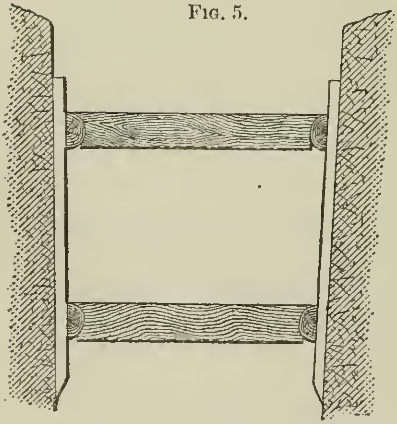
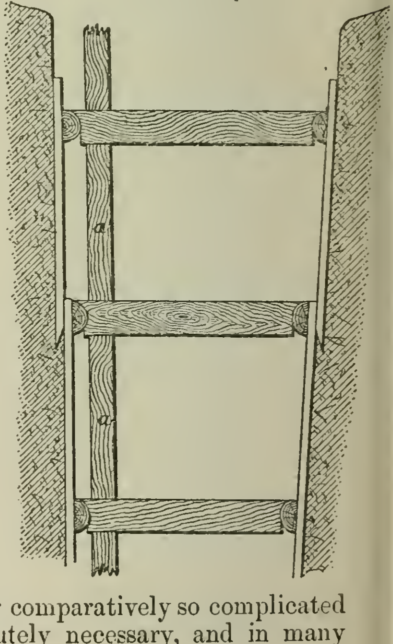
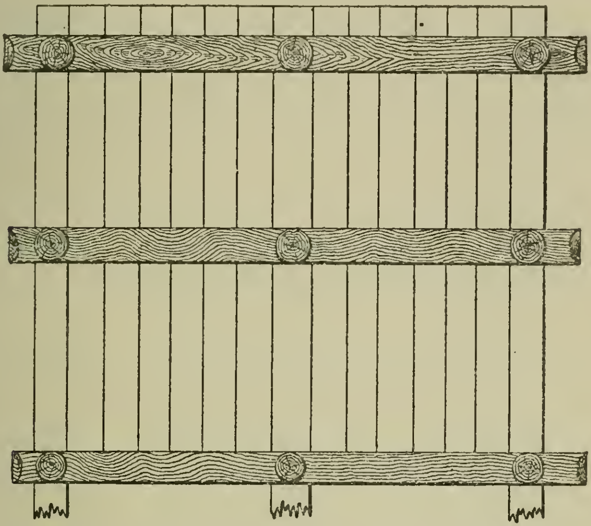


Fig. 6.



Of course a system of timbering comparatively so complicated should not be used unless absolutely necessary, and in many cases, where there is sufficient depth of roof, it is better to carry on the excavation in short lengths and tunnel-in between. But

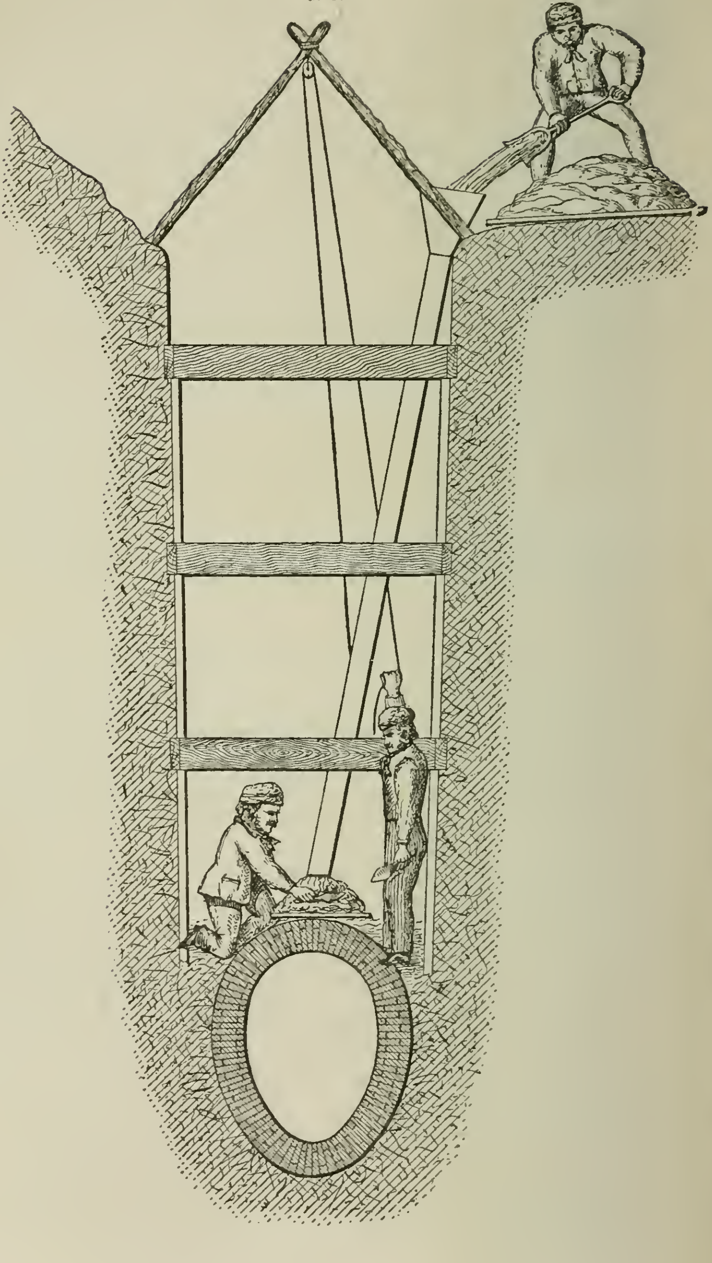
FIG. 7.



there are cases where tunnelling cannot be adopted, and it is better to go to any reasonable extra expense in timbering rather than to risk life. Besides the above reasons, in many instances it is absolutely necessary to leave the timber in until the ground has become thoroughly consolidated. Unless such timbers are of the proper size and have been well framed together, such a precaution is worse than useless, as it gives a fancied security which does not really exist.

There is another use of timber which cannot be said to be confined strictly to cutting trenches for sewerage work, as it is applicable in all cases where masonry is carried on in deep excavations. It has been found more advantageous, instead of carrying down the mortar in hods to supply the bricklayers, to construct small trunks $5\frac{1}{2}$ inches square internally and about $\frac{3}{4}$ inch thick. They are made out of stuff procured by putting two cuts through a batten and fitted with hopper-heads. The lower ends are easily shifted so as to deliver on to the mortar-boards, the trunk being slung by a rope attached to short shear-legs across the cutting. The mortar heap is made close by the cutting as the work proceeds, and one man filling the mortar into the hopper-heads of two trunks can keep four bricklayers going instead of two, or even at times three hodmen

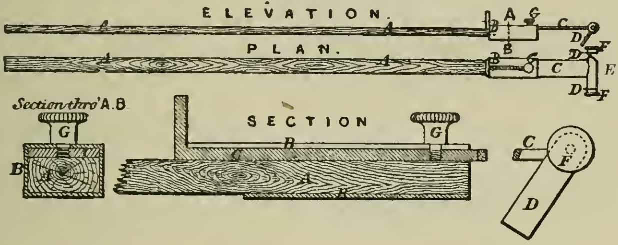
Fig. 8.



who would otherwise be required. This plan has also a great advantage in deep cuttings, where Lias stone-lime is used. The sliding of the mortar down the trunk keeps it chafed up and soft, instead of its constantly getting stiff upon the mortar-boards when carried down in hods. It is shown in Fig. 8.

It is of such great importance that the timbers used in shoring should be accurately fitted together, that simple adjustable gauges, which do not easily get out of order, will always pay for themselves; such may be made for taking angles and splays and also for taking dead lengths at the same time, as in Fig. 9.

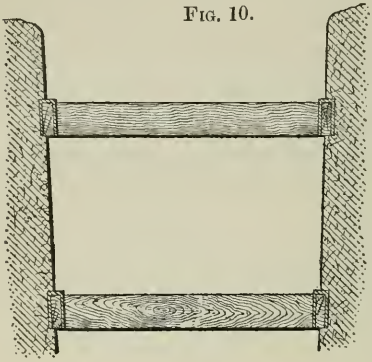
FIG. 9.



Here A is a wooden rod. B piece of iron screwed to A, and having at the top a groove in which the clamp-screw G slides, and which contains the brass slide C. D are arms attached to the cross-bar E, which can be regulated to any angle by the clamp-screws F F.

Although there are great objections to using iron bolts, screws, or spikes to frame shoring together, there are cases where iron may be advantageously used in connection with wood, where shores have to be taken down and replaced in the completion of each length of culvert. The ends quickly wear out, especially if they are driven horizontally, and the shores become too short. The plan of shrinking iron hoops on to the ends of the shores was tried and found to answer very well, and there was a saving of one-third of the timber used in shores, even in a length of 100 yards of culvert. Where the pressure is very great upon the shores they are very apt to split the waling, unless they are cut very accurately, and are of the full size of the plank. It has been found of advantage to provide a few wrought-iron clamps to use in such exceptional cases; they are fixed at the back of the shores, as shown in Fig. 10. There is one way more in which iron may be used with advantage in connection with timber for shoring It is frequently necessary to introduce additional shores at the bottom of a deep excavation for sewerage work, or to change the position of those which are fixed to make room for the masonry. It is often very difficult to drive such additional shores into position, so that the proper pressure may be thrown upon them without disturbing several others. It is proposed to effect this object by making use of a double shore, capable of adjustment in the length, and constructed in the following manner:—A piece of round timber 7 inches diameter, Figs. 11, 12, 13, is hooped at both ends with strong wrought-iron hoops made from $\frac{3}{8}$-iron, 4 inches broad. A groove is then cut down the centre of the piece of timber, 1 inch wide, as far as the hoops at each end, with two cross-grooves in the centre, $\frac{1}{2} \times \frac{1}{4}$. Folding wrought-iron wedges, with projecting ribs to fit the cross-grooves are then introduced in the centre, and driven up till the timber is sprung apart about 2 inches or more, as the case may be, according to the length of the shore. Two other rings made of the same sized iron are then slipped over the ends of the timber, sufficiently large to go nearly as far as the centre wedges. They are to be driven sufficiently tight to hold them firmly in their positions, the shore is then ready to fix in place. When in place the wedges are to be slackened and the spring of the timber will cause the shore to fix itself tight without any hammering or wedging. When so fixed the loose rings are to be driven up against the wedges in order to prevent springing, if an unusual strain is thrown upon the end of the shore. When the shore requires to be withdrawn the wedges are to be driven up again, and in so doing the loose rings are driven back, and the shore being shortened is easily removed. Cast-iron friction rollers, working on wrought-iron pins, are sometimes introduced with advantage at intervals, instead of the wood rounds to the ladders used for conveying materials in deep sewerage trenches; they should of course be rather larger than the rounds. By carrying an endless rope round these rollers, bricks may sometimes, with advantage, be lowered down in boxes instead of

FIG. 10.



Enlarged View of Waling

FIG. 11.

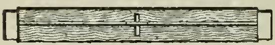


FIG. 12.

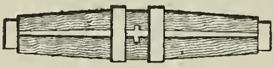
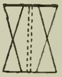


FIG. 13.



being carried down in hods (see Fig. 14). There are many other minor uses for timber for sewerage work, such as centering put together in pieces when common centering cannot be withdrawn, temporary drainage trunks, and other items which need not be particularly described.

Fig. 14.

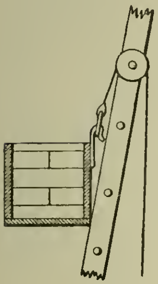
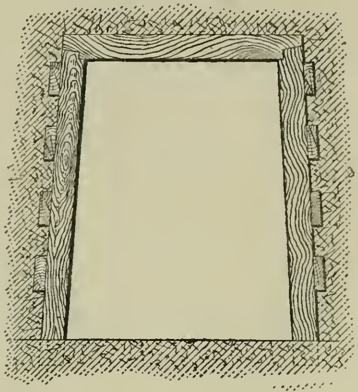


Fig. 15.



Timber in Tunnels, Headings.

The timbering, when the ground is tolerably firm, generally consists of two side posts which are let 4 or 5 inches into the bottom. They should be inclined towards each other, and framed into a head-sill, as in Fig. 15. When the ground is soft or shifting, the side posts should stand on sole plates of half-round timber, or short pieces of plank about 1 ft. 6 ins. long. If it is of a still more shifting nature, it is better to frame the posts into ground sills, either let into the bottom or framed together in a complete system of longitudinal and cross sills, as in Figs. 16 and 17.

Fig. 16.

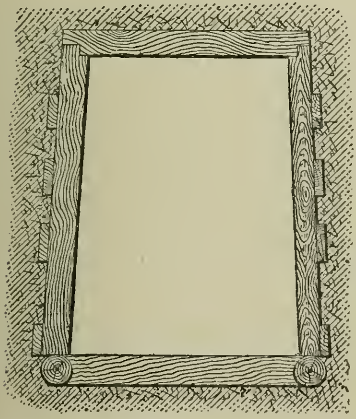
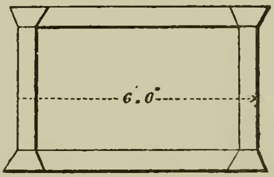


Fig. 17.



When two sets of frames have been introduced at distances of from 4 to 6 feet apart, as the case may be, they are lined at the back with boards or planks, either at intervals or close together, as may be required (see Fig. 18). Pieces of board pointed at the end, commonly called poling boards, are then driven above the head-sill in the direction of the next frame: these should always be driven with a certain divergence outward, in order to make room for the introduction of the following set. This divergence is obtained either by cutting the boards wedge shape, or by driving in slight temporary keys from the front, between the boards and the head-sill; or better still, by introducing a lintel above the head-sill, which is wedged up by two or more hard-wood wedges against the ends of the boards (see Figs. 19 and 20). It is sometimes necessary to drive these boards also at the back of the side

FIG. 18.

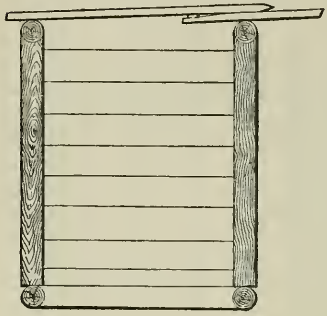


FIG. 19.

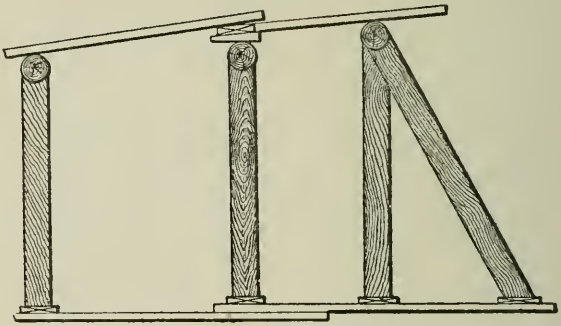
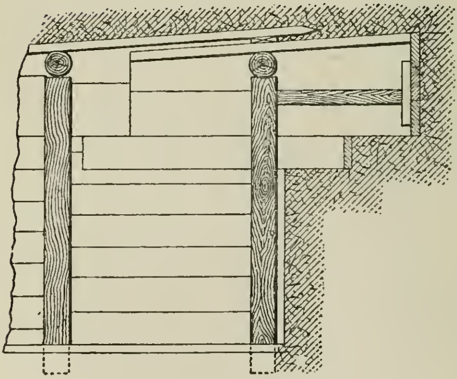
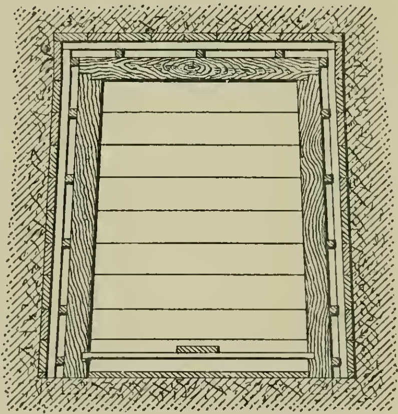


FIG. 20.



posts and under the sills, forming a close timbering, having the section of the frustum of a pyramid. It is also often advisable, in order to assist in obtaining this divergence, to fix a third set of framing, rather larger than the others, in front of the second set, over or outside of which the boards are driven; this must be strutted against the next frame in advance of it. The second set of poling boards is driven forward in like manner, overlapping the others to the extent of 5 or 6 inches. If the strata contain much water it is necessary to secure the face as the work proceeds. It is better in that case to proceed in steps by fixing short planks against the face of the work, and driving shores between them and the next frame, and if necessary, strutting the frame against the one behind it (Fig. 21). The poling boards and the boards forming the lining behind the side posts are then driven forward by degrees, sometimes only a few inches in the course of a day. Various temporary means of strutting and shoring the face are adopted, but these are so numerous, according to circumstances, that it is impossible to give any general rules for constructing them. Experience and presence of mind are the principal guides to be relied on in such cases. Where it is necessary to carry a tramway through the heading, the sleepers should be laid independently of the ground sills.

FIG. 21.



The drainage from a heading should be carried in wood trunks laid upon the ground sills and under the cross-sleepers carrying the tramways. These trunks should be made according to the section and plan in Figs. 22 and 23, with a bottom and two sides tied together by cross-pieces dovetailed into the sides at all the joints and intermediate ties about 4 feet apart. The top should be loose, formed of short pieces with ledges under, of such a length that they may drop easily into the trunk, and may be lifted for the purpose of cleaning out the trunk.

FIG. 22.

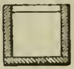
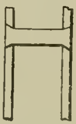


FIG. 23.



CENTERING, &c.

In enlarging the tunnel from the section of the heading to the full size, very little timbering is required in an ordinary way beyond the centering, as the masonry in all cases should immediately follow the excavation as it proceeds. There is always, however, a certain space to support in advance of the centering to allow space for the men to work in. This will often carry itself; at other times it is supported by short ends of boards or planks resting on the masonry, and either shored or strutted against the face. A better plan would be to make use of an inner and an outer centering, the outer slightly overlapping the inner, and being strutted up from it. The front face of the inner or principal centering should stand fair with the fan of the outer centering, but must not overlap it, in order to give room for filling-in round the outside of the arch. The two sets of centering should be moved forward gradually as the work proceeds, and wedged up when in their places. The uprights should be of round timber. All tightening-up should be done with wedges driven between double plates.

In some cases it is very desirable to construct the centering so that it may be taken to pieces. A trussed centering in three thicknesses is the most convenient description of centering for this purpose; one form is shown in Figs. 24 and 25.

FIG. 24.

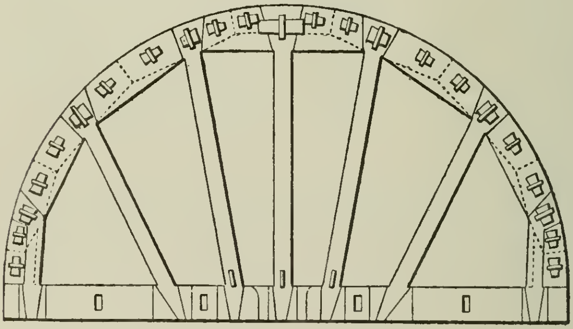
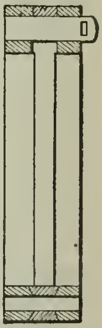


FIG. 25.

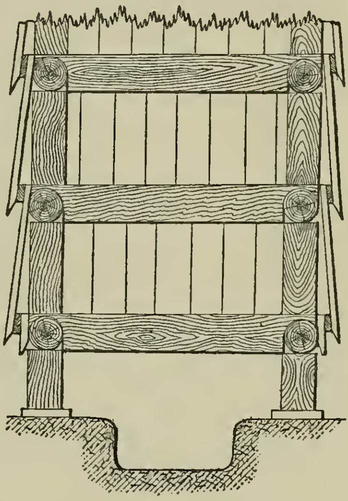


The outside segments of the centering are cut in the usual form, and are jointed on the uprights. The uprights are shouldered to support the middle piece. The uprights and segments are tied together by wrought-iron loops, which are riveted to the one segment, and passing through a mortise in the middle segment and the outside segment on the other side or the opposite upright, are keyed firmly against the upright or opposite segment by a hard-wood wedge driven through the loop.

TIMBER IN SHAFTS.

In some cases a double curb of 3-inch plank with the cross-joints properly broken is laid upon the ground, and the masonry being built upon it, it is gradually sunk into the ground by excavating out the inside and under the curb, various descriptions of iron bond being used to tie the masonry. For smaller shafts a common well-curb is used, rather more strongly constructed than usual. Where timber is plentiful and the conveyance of materials difficult and expensive, a square or rectangular shaft may be sunk and timbered in a similar manner to the shafts adopted for the mines in the Hartz Mountains. A strong curb of round timber is first laid, the timbers being halved together and slightly bird's-mouthed in order that they may fit to the rounded sides. When the ground is very full of water or otherwise insecure, these curbs are laid one upon the other; at other times they are kept at variable distances apart, and lined at the back with 2-inch planks. But, as a general rule, they are lined at the back with boards pointed at the ends, driven to a certain batter by the same means, reversed as those described for driving headings—one set of boards always overlapping the next. A section of this mode of timbering is shown in Fig. 26.

Fig. 26.

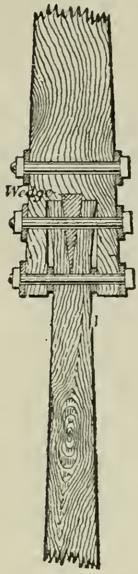


PUMP-RODS.

The long pump-rods for deep shafts are generally of square timber scarfed and bolted together, but where tapering sticks of round timber are readily available, they will make an equally strong and much lighter and more economical pump-rod if used in the form shown in Fig. 27. In this manner the pull upon the timber will be resolved into a pressure from the outside towards the centre, in which direction it has the greatest resisting power.

There are many other purposes for which timber is used in connection with tunnelling, as, for instance, in the windlasses and horse-whims for raising the stuff excavated,—the kibbles or tubs in which it is raised, and the various timber erections and other buildings which are required in connection with the pumping and hoisting apparatus. These, however, vary so much that it would not be possible to describe them properly within the limits of an essay. It is sufficient to say that all framing should be well and strongly put together, and well tied with iron where it is in the open air; and all wearing parts should be of iron, or if that is not possible, of very hard wood; and nothing should be so complicated as to prevent an intelligent miner from taking it apart and putting it together again.

Fig. 27.



It is not supposed that anything new has been brought forward in the foregoing observations. An attempt has only been made to collect together a few memoranda from the author's experience as a railway and sewerage engineer and contractor, and also the results of the information he has obtained while superintending some mines and furnaces in the Hartz Mountains, the timbering of which was carried out under the direction of a very intelligent and experienced German mining captain. Several of the modes of using timber above described were there executed under his superintendence at the suggestion of the author.

DISCUSSION.

Mr. W. Adams said that when he was engaged in the construction of the North London Railway some twenty-three years since he had timbering in cuttings at least 40 feet wide and sometimes over that. Timbering of the description referred to in the paper would not suit such cases as that. It was necessary there to use some of the largest balk timber 16 or 18 inches square, and of course the timbering could not be driven in sideways in the way it often was with small timber. It was necessary to use very large wedges driven in by malls; and the timber being driven in such lengths, it had to be supported from below and braced crosswise. The timber would be placed from 8 to 10 feet apart, or in some cases at shorter intervals than that. They had to be braced horizontally and stayed vertically.

Mr. Kirkman stated in reference to some appliances which he had devised for strutting trenches, that in the case of open cuttings, he proposed to introduce at one end of the strut a screw, instead of driving wedges. That would obviate the jarring occasioned in passing through the streets of a town where there were loose or shifting strata. He believed that no one would deny that the blows from the heavy mall very frequently shook the foundations of buildings, and injury to them was the consequence. The method he proposed was that a screw should be fixed to the end of the shore, and a man there, by means of a spike or a spanner, should be able to bring the necessary amount of pressure to bear against the walings instead of that pressure being given by wedging, as at present. That was the principle he proposed carrying out. It would have just the same effect as the present method, but would be more simple and effect a greater saving in the works. The expense would be very trifling. The author stated in the paper, that in a distance of about 100 yards, more than one-third of the timber would be saved. He (Mr. Kirkman) considered that the saving of timber would entirely cover the cost that the contractor might be put to in using his appliance. As a matter of course it was only experience that could absolutely determine that point.

Mr. LIGHT asked if any member could explain why such unusually heavy timbering was used on the East London Railway, especially on the Wapping side. The timbering was the heaviest, in proportion to the extent of the work, of any of which he knew.

Mr. COLYER observed that the heavy timbering on the East London Railway, at the Wapping side, was necessitated by the great depth of the works, which were carried 66 feet below the level of the street. The necessity for such timbering might be seen in the present condition of Wapping Station, the ground having sunk considerably.

Mr. LE FEUVRE, referring to Figure 14, observed that the bucket appeared to be a very primitive contrivance, and if made as represented would fall to pieces when it contained a heavy weight. He thought that the loaded bucket should be made to facilitate the raising of the empty one.

Mr. JOHNSON asked, with reference to the arrangement shown in Figure 24, whether it would not be possible to adopt a method of decentering by means of stout canvas or leather bags filled with sand, the bags being opened and the sand allowed to run out gradually when it was desired to remove the load. In places where it was impossible to drive the timbers back, or get them back in any way, working by sand in that manner had been found very simple and very cheap.

He would also ask, with reference to Figures 11 and 12, whether, instead of having a spring strut, or the arrangement consisting of a screw attached to each separate strut, as described by Mr. Kirkman, it would not be possible to use either a screw, or hydraulic jacks. The hydraulic jacks were made very light and portable, and they would give sufficient power to jam the walings back, and thus allow the introduction of a strut and a wedge with a very small amount of hammering, and without the disadvantage of shaking.

Mr. KIRKMAN, in acceding to a request for further particulars respecting his proposed improvements in strutting trenches, observed that he proposed to bore a hole in the end of the strut. A plate with a boss would fit on to the end of the strut and fix itself there, and the opposite end would press against the waling; then, either with the end of a spike, or with a square boss instead of a round one, there would be imparted to the strut the quality of elongation the same as was imparted in the case of the pole which was sprung as described in the paper. By those means he would obtain the required amount of pressure; and he calculated that there would be about 3½ or 4 inches of elongation. In those he was then turning out, instead of the screw passing into the end of the strut (which he looked upon as being in some measure objectionable, inasmuch as the timber being generally worked on the ground, the boring the end way of the grain would be awkward) he made the end that went on to the strut with a cap or flange to fit on the outside of the strut. That prevented it splitting, and did away with the labour of boring. He thus got a boss on the inner side of each plate, and a right or left-handed screw. The castings were made with a recess at the end, and the nut in which the screw worked (which was a hexagon or an octagon) was let into the recess. They were easily duplicated, and would, he thought, be found very effective. There would only be one on each strut.

Mr. RIGG said he understood that Mr. Kirkman wanted 4 inches stretching of the strut. That was rather a different proportion than Figure 11 would give, because when the pole was opened out as Figure 12 showed, and closed again, the increase would not be much more than the eighth of an inch; which he did not think would be sufficient.

Mr. TURNER, in replying to the discussion, first thanked the Council for the honour done him in awarding him the President's premium. With regard to Figure 14, in which he proposed to carry the bucket on cast-iron rollers, worked with an endless band, it would, of course, be a very great advantage if a counterbalance weight could be applied as suggested. But, as a rule, when the ladder was against the cutting, there was not sufficient room for a counterbalance weight to go up and down. He did once attach a leaden weight, but he found that there was no room for an empty bucket to ascend while a full one was descending. With regard to the running sand, it was thought that the waling pieces would hang in the sand; but he managed to get over that by making them narrow, sometimes only 3 or 4 inches wide, so that they had not the friction of the sand upon them. He never found any difficulty in driving them down. They were driven down rather in advance. One speaker had proposed a different way of fitting the ribs of the centre together, which would probably answer equally well. His was only one way of showing how it could be done, but it was a way which he had successfully carried out in practice. In all the matters to which he had referred he had only spoken from his own experience, not with the view of saying which would be the best way, but of showing the way in which he had carried such work out himself. The last point discussed had reference to the fixing of the strut. The method described by him was calculated for 6 feet lengths, and the wedges were 2½ inches apart. That would give a difference of about half-an-inch or five-eighths of an inch. According to his principle he always used to cut the shores so that they fitted within the eighth of an inch, so that the amount calculated would be amply sufficient for any allowance in tightening up.

The PRESIDENT, in closing the discussion, observed that the paper was of sound practical value, and would, in the future, be referred to by the younger members of the profession with considerable advantage.

October 2nd, 1871.

J. H. ADAMS, VICE-PRESIDENT, IN THE CHAIR.

RECENT IMPROVEMENTS IN EXPLOSIVE COMPOUNDS.

By PERRY F. NURSEY.

The importance of having in certain engineering operations an explosive compound possessing violently disruptive powers, combined with safety in use, is too well known to require insisting on here. Such a substance having become, in many cases, a real necessity, it is of consequence to the engineer to obtain information respecting the progress made by science in utilizing and bringing into subjection the dangerous substances which nature and art have combined to place at our disposal. In a paper upon the subject of explosive compounds for engineering purposes, which the author read before the Society of Engineers, in February, 1869, he reviewed the whole question down to that time, tracing out the progressive history and development of various explosives, and showing the applicability of some to engineering operations, and the inutility of others for any purpose whatever. It will doubtless be remembered that in that paper gunpowder, in its several varieties, was noticed, as was also Colonel Ryley's old proposition to render gunpowder non-explosive and explosive at will by enveloping the grains in a foreign substance, as well as Mr. Gale's revival of the same idea in recent times. The various nitrate and chlorate powders were then noticed, including the very powerful chlorate powder of Mr. Horsley, Hockstädter's gunpaper (re-patented by Reichen in 1866), Reveley's white gunpowder, Schultze's gun sawdust, and Neumeyer's inexplosive gunpowder were then described and various experiments made with them recorded. The author then referred to nitro-glycerine in its original and dangerous form, and in its new and safe condition, as modified by Nobel, and rendered comparatively harmless. Gun-cotton, and the various improvements introduced into its manufacture by Professor Abel, were then noticed; and finally the then recently-discovered method of firing it with a percussion fuze in the open air, by which means all the resistless energy of the material became developed, was described.

The author has thought it well to give the foregoing brief *résumé* of his previous paper, as it leads up to the present one, in which he purposes to give an account of such practical progress as has been made in explosive compounds since he last addressed the Society upon the subject. Since that paper was read the author has watched the progress made in the development of the question, and an examination of the results shows them to be as follow:—In the first place gunpowder has been improved in certain respects, to meet the requirements of the increased calibre of our heavy ordnance. In the second a new blasting material has, within the last few months, been brought before the public with a view to its introduction into England, by Professor Engels, of Cologne. In the next place a new explosive powder, designed for use in shells, has been brought forward and tried by Professor Abel, and the introduction of a new powder for explosive bullets has been attempted, but has not succeeded in England. Beyond this there have been three distinct modifications of dynamite advanced by Abel, Horsley, and Schultze respectively. The object of each has been to replace the silica in dynamite by substances which would equally well absorb the nitro-glycerine, and yet be explosive in themselves, thus giving a stronger agent as the resulting compound.

The improvements which have been made in gunpowder have reference mainly to the size and density of the grains. The necessity of an alteration of the manufacture in this respect was first recognized in America, where it was rendered apparent by the gradually increasing dimensions of their heavy artillery. The first practical exponent of the theory of large-grain powder was Dr. Doremus, of the United States, who manufactured the powder in small cakes, which were pierced with numerous perforations. We next find Russia producing prismatic powder, which consists of meal powder compressed into flat perforated cakes of hexagonal form, 1 inch thick, and 1½ inch across the extreme points. These prisms are made by a machine, somewhat similar to a table engine, and by which they are turned out with great rapidity. Prussia is also using gunpowder of a similar description for her heavy ordnance. Prismatic powder, however, is inferior in effect to both pebble and pellet powder, and only answers in charges for guns up to about 8 inches calibre. In heavier guns it is found to break up and deteriorate. The other two forms of large-grain gunpowder are known as pebble and pellet powder. Pellet powder is simply pressed cake broken up into coarse fragments, varying in size from a horse-bean to a nutmeg, and of irregular shape, and which are glazed and finished in the usual manner. The manufacture of pebble powder involves a special press, in which the meal powder is compressed into small blocks of regular form and of varying dimensions.

In order to trace the history of the production of pebble and pellet powder in England, it is necessary to revert to the labours of the committee on explosives, under the presidency of Colonel Younghusband. About two years since, the committee specially addressed itself to determining the kind of gunpowder which, when employed in large charges, would have the least tendency to overstrain the gun. Amongst other points, it was ascertained that the rapidity with which elastic gases are produced by the firing of gunpowder is in proportion to the fineness of the grains. It was found that small-grain powder exercised its explosive power most rapidly, whilst that of large-grain powder was developed more slowly. The result of their investigations and experiments showed that in guns of 8 inches calibre a large reduction of pressure was attained by the use of either pebble or pellet powder in battering charges, without any diminution of velocity. Further experiments were then made with 10-inch guns, which confirmed the previous results, and led the committee to conclude that this description of powder might be used in guns of the largest calibre. They believed it would produce an initial velocity equal to that obtained with the ordinary service powder, whilst at the same time the strain on the gun would be materially reduced. In consequence of these conclusions, Mr. John Anderson, the superintendent of machinery at the Royal Arsenal, Woolwich, designed a machine for manufacturing pellet powder, which was erected at the Royal Powder Mills at Waltham.

The machine consists of a turntable of about 6 feet in diameter, toothed on its periphery, and revolved with the hand by a pinion. At right angles with each other on four opposite points of the table are four circular metal plates about 2 inches thick and 18 inches in diameter, each containing 200 chambers, formerly $\frac{3}{4}$ of an inch, but now reduced to $\frac{5}{8}$ of an inch in diameter. The chambers are fitted with pistons worked by hydraulic pressure from beneath, and have also movable stop-covers. When the apparatus is in work two of the sets of chambers—those opposite each other—are undergoing a similar operation at the same time. With the stop-covers lifted and the heads of the pistons about $1\frac{1}{4}$ inch below the upper surface of the moulding plate, the chambers are filled with meal powder, and the upper surface then swept clear. The stop-covers are then fastened down, and the pressure is applied to the pistons, by which the $1\frac{1}{4}$ inch of powder is compressed to $\frac{5}{8}$ of an inch. The covers are then lifted, and the pistons pressed upwards till their heads are flush with the upper surface of the plate, and the pellets lie loose ready for removal. The machine then receives a quarter turn, and the pellets are swept off from these two sets of chambers, while the filling and pressing is being carried on in the other two sets. The pressure on the rams is about 1025 lbs. per square inch, or allowing for friction, say 1000 lbs. The machine is worked by three men, and the pellets produced are clean made and hard. It does not, however, appear that the pellets made by this machine have been introduced into the service, nor has it been found necessary to erect a second of these machines at the Waltham mills.

Realizing the circumstance that the manufacture of pellet powder would become a special and increasing branch of industry, in consequence of the increase in the calibre of heavy artillery both at home and abroad, Mr. Jabez James directed his attention to the production of a safe and simple press for making the pellets. He perfected his ideas in 1869, when he constructed a press on the hydraulic principle. This press was at once adopted by Messrs. Curtis and Harvey, of the Hounslow powder mills. There are now five of these machines, which have been working with perfect success for more than two years past. The author examined these machines a short time since at the Hounslow mills, and was informed by Mr. W. J. Brown, the manager at the works, that they gave every satisfaction. Each machine consists of a strong cast-iron framing and head fixed by bolts to the top of an hydraulic press. Within this framing are arranged horizontally the various gun-metal plates and punches for forming the pellets. The centre plate has a flange on either side, and is supported on a groove formed on the inside of the cast-iron framing, and is bored through with a number of circular holes $\frac{3}{4}$ inch in diameter. The lower plate carries a set of long punches, which form the bottom of the pellets, and which also expel the pellets from the centre plate when formed. This lower plate is supported by the head of the hydraulic press. The upper plate carries a series of short punches, which form the top of the pellet, compressing the meal powder to the thickness of $\frac{1}{2}$ inch. This plate is movable in a horizontal slide on the under side of the head of the framing. It is worked by a screw from a handle in front of the machine, and is thrown to the rear of the press when the holes in the centre plate are being charged with meal powder, and also when the pellets are being expelled and removed. Stops are inserted between the centre and the lower plates, in order to allow of variations in the thickness of the pellets. There are also stops between the flange of the centre plate and the grooves in the framing, to hold the plate in position when the pellets are being expelled. The stops are all self-acting and are governed by the upper plate; when this plate is moved back clear of the perforated plate beneath it, the upper stops are thrown into gear with the centre plate and the lower ones are withdrawn. The withdrawal of the lower stops having permitted the lower plate to ascend further, and its punches to clear the holes of the newly-formed pellets—which are rapidly swept from the plate and the holes recharged—the upper plate is drawn into position again, when the upper stops are withdrawn, and the lower ones inserted. The dimensions of the pellets are ¾ inch in diameter, and ½ inch thick. There are 250 perforations in the centre plate, and each press turns out one charge about every five minutes, or 3000 pellets per hour, with two men working it. The quantity of meal powder used at each charge is 3½ lbs., the pellets consequently run about 72 to the pound. Such is the success of these machines that the author is informed that there is a probability of an order for several more shortly being given.

Although both pebble and pellet powder promised so well in the early experiments of the committee on explosives already referred to, and which were made with the 8-inch and 10-inch guns, it has not yet succeeded with guns of larger calibres. Of this fact the most recent addition to our heavy artillery—the 35-ton 700 pounder gun—affords a notable instance. The proof of this fine gun dispelled all the anticipations of the committee with regard to increased velocity and reduced strain. Not only did the pebble powder inflict an excessive strain upon the great gun, but its use produced irregularities with regard to velocities which involved the powder question in greater perplexity than ever. Another annoying circumstance in connection with the use of pebble or pellet powder is the action of the gases on the bore of the gun under the influence of the great heat evolved in combustion. Although combustion proceeds more slowly with large than with small grained powder, the heat generated appears to be greater, and singularly enough the recoil is more severe. Although the size of the powder grains prevents them forcing their way along the slight space between the projectile and the bore of the gun, yet the burning gases readily insinuate themselves into the grooves of the rifling and act deleteriously on the metal.

The 35-ton gun on its proof was first fired with 75 lbs. of pebble powder and a 700-lb. projectile, the powder charge being gradually increased to 130 lbs. The initial velocity, however, reached its maximum with 120-lb. charges, when it was 1370 feet per second, with a pressure of 47 tons per square inch; with the higher charge the velocity fell off to 1348 feet. This would seem to indicate that 120 lbs. of powder is the utmost quantity that can be profitably consumed in the bore. But here we are met by considerations touching the length of the powder charge in the bore of the gun, and the method of igniting it. In the 35-ton gun, with a calibre of 11·6 inches, 120 lbs. of powder occupy a considerable length of space in the bore, and 130 lbs. of course a still longer space. The vent is placed about 12 in. from the bottom of the bore, and the charge is ignited from the side. This method of igniting the large charges required for heavy guns is open to the objection that a portion of the slow-burning powder is blown out unconsumed, or only partially burned, from the gun. That this is one of the reasons of the vagaries exhibited by the 35-ton gun at its proof the author has no doubt, inasmuch as he has picked up fragments of unconsumed pebble powder from the proof butts at Woolwich, not many yards from the muzzle of the 35-ton gun. A further confirmation of the fact that this will occur, even with guns of smaller calibre, and consequently firing smaller charges, is to be found in the circumstance of the author having picked up similar unconsumed grains of pebble powder which were strewn about over the ground between the guns and the targets on the practice ranges at Shoeburyness. The remedies which suggest themselves for these irregularities are to reduce the length of the charges as much as possible, and to ignite them from the centre instead of from the side or end, whilst a wad or some such device may be found useful in closing the grooves against the passage of the gases. The whole subject, however, is under the consideration of the committee on explosives, in whose hands the solution of the difficulty may be safely left.

It may, however, be interesting to know that satisfactory progress is being made towards a solution of the difficulty as regards reduced pressure and increased velocity. The most recent investigations at Woolwich show that with solid powder pellets $\frac{3}{4}$ in. diameter and $\frac{3}{8}$ in. thick, the pressure was 47 tons to the square inch, and the velocity 1430 feet per second. With pellets $\frac{3}{4}$ in. diameter, $\frac{1}{2}$ in. thick, and having an indent on one face about 3·16 in. diameter, and about $\frac{1}{4}$ in. deep, pressures of 23 or 24 tons per square inch were obtained. But the objection to this form of pellet is that it is difficult to glaze on account of the indent. The next idea was to split the indented pellets into halves, which is done by a small machine at the Hounslow mills, the halves being then glazed in the usual way. With these broken pellets the pressures—even in the 35-ton gun—have, so far, been found to be reduced to 14 tons to the inch, whilst the initial velocities remain at 1430 ft. per second. This forms a remarkable contrast to the 47 tons pressure and 1348 ft. velocity obtained with this gun on its proof.

Turning to the new explosive substances that have been brought before the public since the author's previous paper, we find them to be six in number, as already mentioned. The first of these is lithofracteur, which is a compound of German origin, having been invented by Professor Engels, of Cologne, in which city it has been extensively manufactured for the last three years. It is known and used in the various mining districts throughout Germany, and was probably for the first time brought under the notice of the English public during the Franco-German war. In the course of that memorable struggle, whenever opportunity offered, the French administered to the Prussians sundry violent doses of dynamite. The Prussians responded by dissecting a few bridges and removing one or two villages by the application of lithofracteur. This substance is of a stiff pasty composition of dark grey colour, its component parts being nitro-glycerine, gun-cotton, the constituents of gunpowder, infusorial earth, and one or two other substances. This substance, so far as experience has gone at present, is one of the most violent, and at the same time safe and useful explosive compounds yet discovered. The compound is made up into cartridges by wrapping it in thin paper, the size being 4½ in. long by ⅞ of an inch in diameter. It possesses the same peculiarities with regard to non-explosiveness under ordinary conditions of ignition in the open air as do dynamite and gun-cotton. Lighted by a common match in the air, lithofracteur simply burns out like so much damp gunpowder, leaving a light white ash. When, however, it is fired with a percussion fuze, all its resistless energy is fully developed, and it explodes violently.

In May last a series of practical experiments were made with lithofracteur, in order to demonstrate its power, and at the same time its safety, with the view to its ultimate introduction into England for mining purposes, for which it is eminently adapted. The experiments were carried out at the limestone quarries of Mr. R. S. France, at Nantmawr, near Shrewsbury, and at the greenstone quarries belonging to the same gentleman, and situated in the same direction. Mr. France having used gun-cotton at his quarries, and accidents having occurred with it, was naturally desirous to obtain the aid of a powerful and yet safe explosive—such as lithofracteur appeared to be—in his workings. He accordingly placed his quarries at the disposal of Gebruder, Krebs, and Co., who are the manufacturers of lithofracteur in Cologne, in order that it might be thoroughly tested in England. Accordingly a number of gentlemen connected with the scientific, mining, and shipping interests, were invited by Messrs. Krebs to witness the trials, which were conducted by Professor Engels.

The author having assisted at those experiments is enabled to report upon them from his own observations, and from notes taken at the time. The first series of trials were carried out at Mr. France's Nantmawr quarries, which are situated in a carboniferous limestone range, about 22 miles from Shrewsbury. A railway runs to the foot of the quarries, and the workings are approached from the line by an incline 500 yards long, laid with a double line of rails. The limestone is brought down this incline by gravitation, the full waggons hauling up the empties by means of a wire rope. At the summit of this incline fifteen lines of tramway branch off to various points at the face of the workings, which presents a fine vertical wall varying in height from 120 to 170 feet. The limestone is of a fine close texture up to within a short distance of the top, where it is coarse in grain. This upper portion is burnt for lime at the quarries, where there are sixteen kilns for that purpose. The lower portion is used in ironworks as a flux, for which it is well adapted.

The preliminary experiments consisted of throwing a box, containing 5 lbs. of lithofracteur, from the top of the workings, at a height of about 150 feet, on to the plateau below. The box was smashed up and the cartridges were scattered about, but no explosion or even ignition occurred. A cartridge was then ignited by a common cigar fuzee, when it burnt slowly away. A cartridge was then placed upon a block of stone, and ignited by a detonating fuze, when it exploded with a sharp report, and split the two angles off the top of the stone, leaving it like the gable end of a house.

A number of large stones were then broken up for the purpose of ready loading on to the trucks, for conveyance from the face of the workings. In ordinary, boys bore frit-holes a few inches into the stone, in which small charges of gunpowder are exploded and the stones shattered. Charges of lithofracteur were now used, the holes being tamped with water, and the results being in every case satisfactory. These experiments served to demonstrate the fact that lithofracteur is unaffected by water, a matter of very great importance where mines are situated in wet ground, as well as in subaqueous operations. Another important feature of the water tamping is that if a miss-fire should occur—as indeed it did during these experiments—the charge of lithofracteur can be withdrawn and a fresh fuze inserted without the least risk of danger. In blasting with gunpowder or gun-cotton, should a miss-fire occur, the tamping—which is usually sand or mining *débris*—has to be picked out piecemeal to re-fuze the charge, and it is in this dangerous operation that so many accidents occur.

A series of shots were then fired on the face of the quarry at various points, with bore-holes prepared in the same way as for gunpowder blasts, with the exception that the vertical holes were bored much farther back from the face of the work than they would have been in ordinary. The first blast was a nearly horizontal hole, 3 ft. 4 in. deep and 1½ in. in diameter, charged with about 1 lb. 1 oz. of lithofracteur and tamped with water—water tamping being used throughout the experiments. Large masses of rock were detached by the shot and thrown forward, the face of the rock being cracked and scaled over an area of 19 ft. wide by 12 ft. high. The value of these results will be apparent when it is mentioned that gunpowder would have made no impression at all in these horizontal bore-holes, and in fact would not have been used. A number of other shots, horizontal, angular, and vertical, were fired with equally successful results; one of these, however, deserves special notice. This was a hole 4 ft. 6 in. deep, bored vertically into the limestone on one of the terraces formed in the course of working and at a height of about 20 ft. up the face of the quarry; 17½ oz. of lithofracteur formed the charge which brought down about 20 tons of stone, besides loosening a large portion of the surrounding rock. This result was incalculably greater than would have been produced by a very much larger quantity of gunpowder.

The disruptive power of lithofracteur when fired in the open air with a percussion fuze was then demonstrated by breaking a piece of rail in two. A piece of double-headed rail, weighing 75 lbs. to the yard, and measuring 4 ft. 6 in. long, was supported at each end on blocks 2½ in. high. It was laid on its side, and 1 lb. 3 oz. of the compound was placed in the channel between the two heads. The tamping consisted of a few pieces of paper—the wrappers of the cartridges—and three old tramway timber sleepers. The explosion smashed the sleepers into fragments, and sent them flying through the air, blew 11 in. in length out of the web of the rail, and cut one head through. The rail was much bent, and the other head would have been cut through, but that its nearness to the ground gave it insufficient depth. The experiment was therefore repeated with two similar pieces of rail, placed on supports 18 in. clear of the ground. The charge was 1 lb. 5 oz. of lithofracteur, placed as before, and tamped with paper, and five old sleepers. The explosion made matchwood of the sleepers, hurling the fragments in all directions, and breaking both rails clean through.

The halves of the rails were thrown some distance apart, and a hollow basin was blown out in the ground under the line of the explosion.

So far, the question of power only had been tested, but with the most satisfactory results. It was, however, necessary to demonstrate the safety of the compound, in order to remove the grounds of objection urged by railway companies and others against the transit of explosive materials. Mr. France therefore suggested that an admirable opportunity offered for testing the effects of concussion by allowing a railway waggon to run at full speed down the incline already referred to, and which should be met by another waggon placed at the bottom of the incline, where the bare concussion of the waggons alone would shiver them into fragments. An old mineral waggon was therefore fixed near the bottom of the incline, and a second waggon was taken to the summit. To the upper waggon were attached two cartridges, which were so fastened to the ends of the wooden buffers that they should receive the first blow in the collision. Upon the upper waggon, weighing 1½ ton, being freed, it rushed with tremendous velocity down the incline of one in eight for its length of 500 yards. The waggons upon coming into collision were of course smashed to atoms, as was foreseen, but no report whatever was heard, and upon examining the wreck, the contents of the cartridges were found smeared about the buffers and other parts of the waggons. Upon the suggestion of Mr. Brown, of Woolwich Arsenal—who attended the experiments on behalf of the Government—that an explosion might take place between iron and iron, or even between wood and iron, Mr. France directed two more waggons to be placed on the rails as before, the upper one having the buffers plated with iron. At the author's suggestion two cartridges were also tied on the rails similarly to fog signals, and over which the wheels of the waggon would pass at an enormous speed on its way down. This would determine the question of safety on contact being made between iron and iron. The upper waggon carrying the cartridges was released, but on reaching a point half-way between the top and the bottom of the incline, the velocity with which the waggon was travelling caused it to leave the metals, and a wheel breaking, rendered that waggon useless for the experiment, thus unintentionally illustrating another class of railway accident. The only effect upon the cartridges was that they were crushed out of shape by the fall, but no explosion occurred. Another waggon with iron-plated buffers was then substituted for the last at the top of the incline and run down. On passing the cartridges on the rails two semi-explosions occurred, the reports of which were not louder than would be made by a percussion cap being struck with a hammer. The great bulk of each cartridge was simply spread over the surface of the rail. On a subsequent examination of the spot, it was found that only a portion of the cartridge had ignited, that being a minute fraction which was exposed to the exact point of impact. The ignition, however, did not extend to the surrounding portion of the cartridge. A similar report to the last was heard when the waggons came into collision, and on an examination of the wreck being made the buffer plates were found some yards off with the lithofracteur still adhering to them. The contents of the cartridges on the rails were found spattered about in all directions, some having been carried along by the wheels and deposited on the rails. Nothing could be more satisfactory than the results of these experiments, which it will be conceded demonstrated most conclusively the safety of lithofracteur under the most trying conditions in which it was possible to place it.

The experiments at the Breidden greenstone quarries were similar in their general character to those at the Nantmawr limestone quarries, and gave equally satisfactory results. The rock here is of a very hard and dense character, and is largely used for road-making, for which purpose it is well adapted. It was from this quarry that Telford obtained stone for the Holyhead road, when carrying out that work. The stone being much more difficult to work than the limestone, tested the power of the lithofracteur to the utmost. It appeared, however, as though the tougher the material to be displaced the greater the energy of the compound was developed. The final experiment was designed to show the applicability of lithofracteur to subaqueous operations, and its fitness as a charge for sea-torpedoes. For this purpose a charge of 3 lbs. of the compound was secured under a timber raft about 6 feet square, and which was floated out into the river Severn. It was then gradually loaded with stones until it sank in 6 feet of water. The fuzees were then lighted, and the party retired to a safe distance to await the explosion. This occurred in a few minutes, and threw up a fine column of water, mixed with *débris,* some 60 feet into the air. Several of the larger stones with which the raft was weighted were thrown up to twice the height of the column of water, and a few were afterwards found on the adjacent banks of the river. The waters were greatly disturbed, presenting for some distance a mass of seething foam, interspersed with fragments of timber alternating with dead fish. The whole of the experiments were so thoroughly conclusive as to leave no room for question, but rather to give ample reason for expecting that lithofracteur will one day be allowed to find its way into the

English market for blasting and similar purposes, for which it is so eminently adapted. The author is personally acquainted with a number of quarry proprietors and others who are anxiously awaiting the time when this or some other equally advantageous compound can be procured to aid in the further development of some of the most important mineral industries in the kingdom, and even in the world, but which are now more or less in abeyance for the want of a sufficiently powerful and safe blasting agent.

The author may here mention that he has been informed that a company has recently obtained a licence from the Secretary of State for the manufacture, storage, sale, transport, and use of dynamite, and other relative explosives, and that they are about to erect works near Glasgow for its manufacture. The author is not aware of the terms of the licence, but from the uncommon broadness of the permit he should imagine the safety clauses to be as uncommonly narrow and restrictive.

The next original explosive to be noticed is the picric shell-powder of Professor Abel. This powder is obtained from picric acid, and is mixed with saltpetre, forming a bright yellow powder, which exhibits no tendency to ignition from friction. Its detonating powers require a violent blow for their development, and the powder must be closely confined. It appears therefore very applicable to the purpose of charging shells, its explosive power being greater than that of gunpowder, but less than that of either gun-cotton or dynamite. Some trials were made with picric powder at Shoeburyness in July last, at which the author was present. They consisted in firing shells charged with the powder from a 9-inch gun against an iron-plated target. The results were not such as to immediately establish the value of the powder, although they were sufficiently satisfactory to justify a further course of experiments with this substance, which appears to possess all the requirements of a shell-powder.

About a year since, some experiments were made in England with Pertuiset powder, a substance imported from France, and used for charging explosive bullets. Several horses were slaughtered by means of these bullets, and their skulls, ribs, and leg bones were beautifully shattered and mangled by their assistance. The secret of this powder was offered for sale to the Government, who very properly declined to recognize such a barbarous invention. The author understands, however, that several other European governments have made terms with the inventor.

We now come to the class of improvements which have for their object the utilization of nitro-glycerine. It will be remembered that Nobel first utilized it by mixing with it about 25 per cent. of silicious earth. Engels, in his lithofracteur, substitutes for the silica, substances which are of themselves violently explosive, and which therefore tend to increase the power of the compound by so much silica as they displace. This appears to be the object of the three inventions of this class about to be described. The first of these is Professor Abel's glyoxiline, which consists of granulated gun-cotton mixed with saltpetre and nitro-glycerine. Some effective blasting and engineering operations were carried out with this compound upon its first introduction.

The second of these applications of nitro-glycerine is due to Mr. Horsley, whose blasting powder was described in the author's previous paper. The powder is a mixture of chlorate of potash and gall-nuts, and Mr. Horsley has found that by mixing it with 25 per cent. of nitro-glycerine, he obtains a most violent explosive. It is fired in the same way as lithofracteur and dynamite—with a percussion fuze. It possesses the advantage over dynamite of not losing its susceptibility to detonation at low temperatures. When confined, it can be fired without the use of a cap, by means of concentrated sulphuric acid. It is being used with considerable success in some mines in Norway, and has been tried with very good results in some Welsh quarries. Mr. Horsley has also devised a method of protecting nitro-glycerine by mixing with it finely-powdered alum. When the oil is required for use the alum is dissolved out by water. This is a safe method of storing the nitro-glycerine for use in manufacturing the various compounds into which it enters.

It now only remains to notice the method adopted by Captain Schultze for utilizing nitro-glycerine. Captain Schultze is the inventor of wood-powder, which is sawdust treated with acids, and afterwards with nitrates. This powder he mixes with 17 per cent. of nitro-glycerine, which gives a powerful explosive, although one possessing less energy than dynamite.

From what has already been stated, it will be abundantly clear that there are two explosive compounds in particular, of the nitro-glycerine class, which combine safety with power, and which it would be very desirable to have introduced into this country. These are dynamite and lithofracteur, both of which the author has singled out from the rest of the nitro-glycerine preparations because they have been tested well and fully on the Continent by long usage. But the reason why these substances are not in general use in this country, as they undoubtedly ought to be, is mainly owing to the prohibitory clauses of the nitro-glycerine act. This act served an essential purpose at the time it was framed, inasmuch as it gave security to the subject against accidents from the transport and storage of that most dangerous oil. But the act went too far, in that it included all substances into the composition of which nitro-glycerine entered. It is true that there was the opportunity afforded of obtaining a licence from the Government, but so difficult was the process of procuring it, and so peculiarly stringent were its terms, that it was all but prohibitory to the manufacturer of any compounds containing nitro-glycerine, or his agent. But it is satisfactory to know that the question of relaxing this law is now under consideration of the Government, and inasmuch as the Nitro-glycerine Act provides for the introduction of substances containing that oil, if their safety can be proved, it is not too much to hope that the point will be gained. Of course it will be said that we have gun-cotton to fall back upon for use in our mines and quarries. This is true, but it is also true that accidents with gun-cotton are by no means unknown in our mines and quarries, and these have shaken faith in its merits, which faith has been by no means strengthened by the recent catastrophe at Stowmarket. It therefore follows that the public must have some other material in 'which they can place a well-grounded confidence. In the present position of the question the choice lies between dynamite and lithofracteur, both of these substances having been proved to be practically safe as regards use, storage, and transit. With respect to the latter condition—that of safety in transit—it is to be observed, that as far as the author's experience goes, the crucial tests to which lithofracteur was submitted on Mr. France's incline, are absolutely in favour of that substance. It is, of course, open for dynamite to be submitted to a similar series of tests for safety under collision, but the author much questions whether dynamite would stand such tests as lithofracteur underwent. At any rate, the dynamite which he examined, some three years since, he is pretty sure, from the looseness of its composition, and want of cohesion in the particles, would not. But even assuming that it did, there are yet other points which have to be considered in determining which is the better material. This is what the engineer really requires to know, and this is what a paper, professing to guide him in his choice, should point out.

Let us then first compare the two substances, dynamite and lithofracteur, as regards their composition and action. Dynamite consists of 75 per cent. of nitro-glycerine and 25 per cent. of an incombustible material. Hence it is clear that not more than 75 per cent. of any given quantity of the compound can be converted into power by ignition. On the other hand, lithofracteur contains about 60 per cent. of nitro-glycerine, and about 35 per cent. of combustible and explosive absorbent media, there being some 5 per cent. only of incombustible matter in its composition. It follows then as a natural consequence that lithofracteur gives out about 20 per cent. more power under conditions of work than does dynamite. So far their relative powers, as determined by their compositions. We will now look into their methods of manufacture. The base of each is nitro-glycerine, one of the most—if not the most—dangerous and treacherous substances that has been applied to practical purposes. Nobel manufactures his dynamite with nitro-glycerine, prepared according to the ordinary formula, which includes no guarantee of safety. This fact is established by the explosion of nitro-glycerine which Mr. Nobel informed the author had taken place in his factory at Stockholm in 1868, and to which he referred in his previous paper, when illustrating the non-explosiveness of dynamite by concussion from adjacent explosions. Hence there is an ever-present element of danger in the manufacture of dynamite. Herr Engels, however, in making nitro-glycerine for the manufacture of lithofracteur, prepares it according to a special formula devised by and known only to himself, whereby he obtains perfect immunity from accident with that dangerous compound. The absence of accidents at the lithofracteur factory of Messrs. Krebs and Co., in Cologne, may not be a positive proof of this position, but it may be taken as negative evidence of the safety of the process of the manufacture as carried on there. Hence we conclude lithofracteur to possess a greater explosive power than dynamite, weight for weight, and to be attended with less danger in its manufacture. And here, perhaps, the author may be allowed to compliment Professor Engels upon the singular uniqueness of his discoveries, which reflect credit upon his name, and proclaim a mental capacity of no ordinary stamp, even in Germany, where the average of intellectual power reaches so high a standard.

It may be expected that before concluding the author should offer some observations upon the late lamentable explosion of gun-cotton. To treat the subject properly would require an investigation which the author has not been able to make, and would moreover afford matter for a separate paper of itself. Any opinion, therefore, which he may express must be understood as being based upon a general knowledge of the nature and manufacture of gun-cotton, and upon a perusal of the evidence taken at the inquest at Stowmarket. Referring to previous explosions, as well as to the last one, it is notorious that they have all happened on extremely hot days, generally the hottest day of a hot season. It has hitherto been considered as barely within the limits of possibility that sound, pure gun-cotton would explode at a temperature such as could be raised by solar heat in a store, although some of the witnesses at first referred the explosion to that cause. On the other hand, nothing is easier than for impure gun-cotton to decompose and ultimately to explode spontaneously. This is, in fact, the inevitable end of impure cotton, if left to itself. At first sight, then, it might seem that there was some impure gun-cotton in the magazines at Stowmarket. But how could it possibly get there under the strict and careful supervision which appears to have been observed in Messrs. Prentice's works? The washers, the poachers, the driers, the tests, all were carefully tended, and no one seems to think that acid could get where it ought not to in the manufacture, unless done wilfully, and as there appears to have been no motive for such an act, this hypothesis must fall to the ground. As for the foreign emissary—well, the least said about such a piece of bogyism the better.

But assuming that acid did get into the cotton so vastly in excess as it was found to be in the Upnor samples, and that discs of this impure cotton did get into the magazines, why were not other impure discs found on the works. If the author rightly remembers the evidence, no unsound discs were found on the works, only sound ones, and these too were blown from the magazine by the explosion. Again, if the store at Upnor was part of the batch at Stowmarket, why was not there an explosion at the former as well as at the latter place, and at Upnor before Stowmarket, as some of the cotton had had longer time to decompose? Further, why should the cases at Upnor be found to contain a disc here and there to which sulphuric acid had been added in great excess of what was ever put into the cotton in course of manufacture? How could the acid have been put in at the works with cotton in course of being packed without detection? To the author's mind investigation has not been pushed sufficiently far to clear up these and one or two other points, which he cannot deem otherwise than mysterious. Two things, however, are patent. The first is that a misplaced confidence in the non-explosibility of gun-cotton, when ignited by ordinary means, cost Mr. Edward Prentice and his nephew their lives, and the sad circumstance has disposed of a hitherto comfortable theory, founded on experiments which gave it the semblance of fact. The second is that acid was found to have been deliberately placed in the cotton at Upnor, but what possible motive there could have been to so place it at the works, or whether it was placed in it at the works, the reported evidence does not show. The author holds that there remains behind a mystery, the solution of which he does not find in either careless or revengeful workmen, nor even in foreign emissaries.

It has been admitted by the advocates and supporters of gun-cotton, as well as by the Government officers interested in promoting the safety of explosive compounds, and in protecting the public, that there is a necessity for further investigation into the nature and properties of that material. This clearly implies that gun-cotton is not to be relied on for inexplosiveness under circumstances of ordinary ignition. It occurs to the author that the direction in which investigation should be pushed, is that which relates to the protection of gun-cotton from itself. Of course Professor Abel's process of pulping and compressing have done this, to what now appears to be a certain extent, but not entirely. There is a strong analogy between nitro-glycerine and gun-cotton, the base of each being a vegetable production. In the former we have glycerine—a large proportion of which is prepared from palm oils—combined with nitric and sulphuric acids; in the latter we have cotton in a similar combination. Now nitro-glycerine—the result of the first combination—has been converted from an extraordinarily dangerous to a remarkably safe agent, by admixture with foreign substances. Gun-cotton—the result of the second combination—has been made much more safe and reliable than it was by mechanical manipulation. It is for practical chemists to push investigation farther, or rather to recommence it, by considering the analogous nature of the two bases, and by this light endeavouring to ascertain whether something more than mechanical treatment is not still necessary to render the stability of gun-cotton more perfect than it is at present. If, however, the explosion at Stowmarket was caused through some mysterious or occult agency, then the sooner facilities are afforded for the introduction of an explosive compound which carries with it no fear of any such results, the better will it be for the interests of humanity, of science, and of enterprise.

DISCUSSION.

Mr. Orlando Webb observed that there were two forms in which gun-cotton was produced, in the form of a rope, and in solid discs such as exhibited by Mr. Nursey. The rope gun-cotton had been found very dangerous in use, inasmuch as sometimes it would adhere to the sides of the hole while it was being forced down, and the result had been that explosions had occurred. In the Report issued to the Government by Mr. Abel upon experiments carried out at Mr. Beaumont's quarries in Northumberland, Mr. Abel mentioned the fact that an accident had occurred with that kind of cotton a few days before he went down. Unfortunately while compressed gun-cotton, being in a solid lump, was more easily put down the blast-hole, there was yet one difficulty attending it. The upper part of the blast-hole was very much larger in circumference than the bottom part, and when the compressed gun-cotton was put down, although it would easily slip through the upper part of the hole it did not always get down to the bottom, and if the miners attempted to force it down it was liable to explode in their faces. That was one of the dangers that was not met with in the use of either lithofracteur or dynamite. In lithofracteur the material was soft and was easily forced down. As had been observed by Mr. Nursey in his paper, there was the great distinction, that with regard to gun-cotton, if the hole was damp the virtue of the gun-cotton would be destroyed, but both lithofracteur and dynamite exploded very readily under water. The advantages therefore of lithofracteur and dynamite over gun-cotton were very great, both as regarded safety and adaptability for any kind of mining or quarrying work in either wet or dry ground.

Mr. R. S. FRANCE observed that, from his practical acquaintance with the various explosives, he could bear testimony to the correctness of what had been stated by Mr. Nursey and also by Mr. Webb. He (Mr. France) had no prejudice against any explosive that did its work well—or rather he formerly *had* no prejudice against any explosive until, by an explosion of gun-cotton at his quarries, two of his men lost their lives. The result was that the other men would no longer use gun-cotton, and he was therefore compelled to resort to another explosive. He always found that, to a certain extent, gunpowder was an inefficient explosive. Its very nature and composition showed that, under most circumstances of blasting, it was not calculated to effect the object properly. Its action was entirely different from that of the other explosives, whether it was gun-cotton, lithofracteur, or dynamite. In making those remarks he did not wish to say anything against gun-cotton. He had seen gun-cotton in use for years; it was a very nice clean substance to handle, and a very powerful explosive. There was nothing to be said against it, except that it had those disadvantages which had been pointed out. Being used in the form of hard compressed discs, and the upper portion of the hole in boring being made of greater diameter than the lower portion, there was great difficulty in getting the discs properly adjusted to the diameter of the holes at the bottom. The successful results of all blasting laid in getting the explosive as nearly as possible to the bottom of the boring, and the success of the charge was in proportion as the action of the explosive took place at the bottom of the hole. That was where gunpowder always failed. Those who were acquainted with blasting operations came to the conclusion that gunpowder did not answer. Gunpowder would send shot and shell to immense distances—distances almost incredible, and it might therefore be asked why that same force, confined within a bored hole of 1½ in. or 1¾ in. in diameter, was not capable of exerting the same power as it did when put inside a gun or mortar or any other weapon of war. The difference arose from the fact that the action of gunpowder was an upward action. To illustrate his (Mr. France's) meaning he would assume that a vertical hole, 5 feet deep and 1¾ inch in diameter, was bored —say in a limestone bed. It would have to be filled nearly two-thirds with gunpowder. There were two modes of firing gunpowder, either with a fuze, or with a pricker and a straw. The pricker and straw formed a very primitive mode of firing, but he (Mr. France) thought it was the best. In firing a hole charged with gunpowder where a fuze was used, the fuze must be put in first. It was obvious that an elastic tube like a fuze could not be put down through the gunpowder, therefore the fuze must be put in first and the gunpowder afterwards. The tamping of the hole by hard rapping was effected in precisely the same manner, whether the fuze was used or whether the pricker and straw were used, and the firing was very much the same. But it so happened in all practical blasting operations that there were frequently miss-fires. The best fuze sometimes had not a continuity of gunpowder, and the disadvantage of the fuze was that if the charge missed fire through a non-contiguity of the gunpowder in the fuze, it was then almost impossible to fire that hole out. The only thing that could be done was to bore it out, and that was a very dangerous operation. Men did it, but they continually wetted the tamping, and took it out in small quantities. It might be asked why the charge was drawn at all. The reason was that there was an objection on the part of the men to working a rock in the face of a charged hole, and although the holes might be safe, still there was a prejudice against working with them charged, and the men would rather hazard their lives in another way—in trying to get the charge out—than work in the face of it, therefore the fuze had to be withdrawn before the men would continue their work. The advantage of a pricker and straw was that if the straw failed in the same way that the fuze did—through non-continuity in the powder—the pricker was simply inserted into the hole and another straw was put in, and the shot fired in that way. He would next direct attention to the circumstance that gunpowder was so very different in its action from the new explosives. Gunpowder exploded in an upward direction. It was found that in using gunpowder, if it was not so arranged that the fine powder ignited at the bottom of the hole, particularly before any of the coarse-grain powder ignited; the result was what was called a "double barrel." The upper portion of the charge exploded first, and simply blew the top off, and the remainder being liberated, exploded without doing any good at all. Therefore the best arrangement was to have some very good fine powder in the straw which would run very rapidly down. For blasting purposes coarse-grain powder was most effective, and effectiveness was the secret of success. The reason was that coarse grains did not form such a solid mass in the hole as fine powder did. The grains were polished and irregular in form, and would not set in a body. The consequence was that there were small interstices by which the fine powder got down to the bottom of the charge. There was greater freedom by which the fine powder, when ignited, entered the charge of the blasting powder, and the fine powder, being more easily ignited, rushed down the straw and fired the whole charge at once. Occasionally there were, as he had observed, the double-barrelled shots, but as a rule the men so managed that the finer gunpowder was carried down to the bottom of the hole before any was fired, and on that rested the practical effect of the boring, the object being to displace the greatest mass of rock. There were many advantages in the more modern explosives over gunpowder, no matter whether it was lithofracteur, nitro-glycerine, dynamite, or any other violent explosive. Their action was downwards entirely; they were fired from the top. In the first place there was a soft cartridge, and it did not matter whether it was exactly the size of the hole, as by means of a stick it was readily got down the hole, one cartridge being pressed on to another till the bore-hole was filled with a solid mass. There was no necessity to put a pricker, or a fuze, or anything down the charge, because the action being downward, the charge was fired from the top; and it was obvious that when there was a downward action the force was exerted in the right direction. When the action was upwards the stones would be shattered and would fly away from the top, but the bottom would be left untouched. Those were the reasons why lithofracteur and other new compounds were superior to gunpowder, although at present, unfortunately, quarry proprietors were confined to the use of gunpowder, in consequence of a very stringent Act of Parliament which virtually prohibited the use of nitro-glycerine compounds. He (Mr. France) would particularly guard against an absurd notion which had prevailed lately, to the effect that certain explosives were safe. Why the very name of an explosive ought to suggest that it was dangerous. There was no such thing as a safe explosive. The moment it was treated as safe it became dangerous, and as long as it was treated as dangerous it was safe, and when those positions were reversed an accident would most probably occur.

The PRESIDENT said the meeting would be glad to hear some observations from Captain Harvey, who had made many experiments with various explosive compounds, especially with regard to their employment in sea-torpedoes.

Captain HARVEY, R.N., said he was of opinion that, as far as torpedoes were concerned, the nitro-glycerine compounds must eventually come into use for charging them, and for which purpose they were admirably suited. If there was a miss-fire the torpedo was still able to act because water did not affect its charge, and that was a very great point. He had made some experiments with dynamite some three or four years ago and he had great confidence in it, having kept it in store for several years. He had also used Horsley's powder, of which he had a good opinion. He thought it so safe that he sent six hundredweight of it to Russia for torpedoes. He had never heard of an accident with it. It was not so strong as nitro-glycerine, but it had four times the strength of common gunpowder. In his (Captain Harvey's) torpedo practice he was confined to certain limits in size for torpedoes, and therefore he wished to get a material embodying the greatest amount of power that could be safely stored within a small compass, and which could be carried in ships with safety. That was a very important point, because, if ships were to carry it, he (Captain Harvey) would not feel comfortable in introducing any compound possessing the least element of danger to the ship. But there were compounds which were perfectly safe. He had used dynamite in this country, but could not answer for its behaviour in tropical climates. He had also witnessed a series of experiments with lithofracteur, and, as far as his observation went, he considered it to be perfectly safe, and he would have perfect confidence in using it in torpedoes. Of course there was a question of time as affecting its stability, but that was a question for time to dispose of. With respect to Horsley's powder, it was as strong as all the other nitro-glycerine compounds, and it had the advantage of an explosive base. There were some advantages and some disadvantages connected with it. As regarded the use of explosives in torpedoes, the size being limited, nitro-glycerine in one form or other would eventually have to be used.

Mr. O. WEBB said that from the experience he had had with dynamite and lithofracteur he was of opinion that the latter was as good as the former, and would produce the same results. He believed the great advantage resulting from the power of nitro-glycerine, or of dynamite and lithofracteur, when fired at the bottom of a hole, arose from a slightly different action from that which Mr. France had ascribed to it. The effect of firing gunpowder was to develop a comparatively slow combustion, and with large grains of gunpowder the fire acted first on the outside, and then it had to burn through the mass; there was thus a comparatively slow movement in the burning of the gunpowder. It was usual to consider that the firing of guns was a very smart and sharp process, yet unquestionably the firing of nitro-glycerine compounds was very much quicker, and the result was that when a charge of nitro-glycerine or any of the compounds of nitro-glycerine was fired, it exploded instantaneously, like a flash of lightning. It had not time to find a weak point. With regard to the action of a powder charge, taking a bore-hole five feet deep, charged with one-third instead of two-thirds of gunpowder, the result was that the action of the powder was at the top rather than at the bottom of the hole. It was constantly found that in slate or other rocks the effect of the charge was from the top of the hole. With regard to nitro-glycerine and dynamite and lithofracteur the effect appeared to be at the bottom of the hole. The explosion was so instantaneous, that it seemed as though the force generated had not time to find out the weak points, and consequently it acted not only in the bottom of the hole, but below the bottom of the hole.

Mr. FRANCE said that no doubt Mr. Webb was right with regard to nitro-glycerine compounds, but with respect to the action of gunpowder it was not altogether the slowness of that action, but its direction, which made a difference. With regard to the size of the holes which were used in blasting operations, he (Mr. France) had already mentioned that the upper portion of the hole was larger than the lower, and that there was some difficulty in getting the hard discs of gun-cotton down to the bottom. That was the case not only with hand-bored, but with machine-made holes. There was a boring machine which had been patented by Captain Beaumont and Mr. Charles Appleby. It was worked by a steam engine and bored several holes at the same time, and those holes were supposed to be, and in fact at first were, of precisely the same diameter from one end to the other. He (Mr. France) had lately visited the extensive works of the Wigan Coal and Iron Company, where that machine was in use. It was a horizontal boring, in fact a tunnel. The holes were bored by steel tubes. The rock was of a very hard nature, and at the time of his (Mr. France's) visit gun-cotton was being used. Seeing that the men were pressing the discs into the holes, he mentioned to them the accident he had had at his quarries. They did not, however, seem to think much of it, but about a fortnight after one of the men was killed and another maimed for life from the very result about which he had cautioned them. They were trying to press the discs too tightly into the hole, and an explosion took place. The reason of the tightness of the holes was that the steel tubing with which the holes were pierced wore away. It was intended for the 2½ in. boring. The discs did not grow larger, but the holes grew smaller through the steel tubing wearing away, and it was in consequence of those holes being of less diameter than they should be that the discs, which were originally of the correct size, were too large and had to be forced in. That went to prove that while gun-cotton was a very powerful explosive, great caution must be exercised in its use.

Mr. O. WEBB said there was another matter which it occurred to him should be considered in connection with the use of explosives in mining operations. That was the question of the difference between the explosion of gunpowder and of the nitro-glycerine compounds in dangerous mines. Gunpowder unquestionably gave out a large dangerous body of flame when it was exploded; a very different effect, however, was produced from the explosion of nitro-glycerine or any compounds of nitro-glycerine, as would be seen from the following circumstance:—In the neighbourhood of Wigan the Duke of Beaufort's trustees were sinking a shaft to get to the coal. The deeper they got down with the shaft the greater the quantity of gas met with, which at last became so serious as to impede the progress of the work. The miners also met with a great deal of water, and the result was that they obtained a quantity of nitro-glycerine which they used. They found on firing the nitro-glycerine that it did not set fire to the gas as gunpowder would have done, but it blew the gas away. He (Mr. Webb) mentioned the fact in the hope that dynamite and lithofracteur, which certainly seemed to be safe compounds of nitro-glycerine, might be tested. He believed that if they were used in mines, they would be the means of saving a large number of lives. The Haydock Colliery and other similar accidents clearly arose from the use of gunpowder, the gas being ignited by gunpowder shots. If dynamite or lithofracteur had been used they could not have taken place.

Captain MACEVOY said that he concurred in the observations which had fallen from Captain Harvey. His (Captain MacEvoy's) experience with explosive compounds, like that of that officer, had been chiefly in connection with torpedoes, and matters relating to them. As regarded the explosive best adapted for sea-torpedoes, which, of course, were submerged, he considered that the nitro-glycerine compounds were decidedly the best. They had the special advantages alluded to by Captain Harvey, the chief of which was that their efficiency was not impaired by the water or by damp.

Captain HARVEY rose to offer a few further remarks respecting the use of powder in torpedoes. There was, he said, a great difference between the case of mines and that of torpedoes. In mines there was the question of expense. In torpedoes there was no such question. In torpedoes it did not matter what the explosive cost; but in mines that was a matter of very considerable importance. What was further required in a charge for torpedoes, such as the sea-torpedo he had introduced, was safety in storage. The weapons would have to be stored on board ship, which was different from keeping them stationary. If a stationary torpedo blew up, being by itself, it would not do much damage; but where fifty or sixty of them were stored together in a line-of-battle ship, it was of great importance to have a charge that would be safe to carry, say, to the West Indies, or wherever the ship might be ordered to. The question of expense did not arise in connection with torpedoes, the great point being safety of storage, combined with great power and certainty of action.

Mr. MACKIE said he must express himself with a considerable amount of caution on the very difficult subject of explosive compounds. For many years he had had experience of gun-cotton, and of other explosives; and he thought that no explosive ought to be treated as safe. It was a very curious thing that in gunpowder works, taken on an average, the number of accidents, for the number of men employed and the time during which they were employed, was much less than in any ordinary trade. It was so even in cartridge factories. That showed how that, with care and caution, by treating the material used as dangerous, even a very dangerous operation could be rendered practically, or, at any rate, comparatively, safe. The great danger and difficulty with respect to gun-cotton had been the unwarranted confidence which had been placed in it. If gun-cotton had been less trusted, probably there would have been fewer accidents with it. He did not think that if it had been less trusted, the explosion at Stowmarket would have been avoided, because it was a remarkable fact that gun-cotton had never been stored in any country where the result had not been that on hot days in July and August there had been an explosion. It had been so in France and in Prussia; and it was so in England for the first time in 1852, in the early days of it; and it had since been so at Stowmarket, Faversham, and other places. Mr. Nursey, he thought, made a mistake—an unintentional one—when he stated that nitro-glycerine and gun-cotton were of the same base. Glycerine came from oil, and was, in reality, more of an animal substance than a vegetable one; and he (Mr. Mackie) thought that, so far as that went, there was a great chemical difference to be observed between the stability of a nitrogenous compound formed upon a vegetable basis, and that formed upon an oily, or animal, basis. In its very nature, cotton itself was an unstable substance. Cotton would explode, or rather it would be the subject of spontaneous combustion, in warehouses, in holds of ships, and even in hot countries, when spread out on the ground in a dry atmosphere. He would particularly draw attention to the tenacity with which many still held to the theory of the non-liability of pure gun-cotton to spontaneous explosion, or to actual explosiveness. It was said that gun-cotton, if placed in the open air, would burn freely, and would not explode; and he himself, on very many occasions, burnt considerably larger quantities than that which Mr. Nursey exhibited, which was about one pound, in that way. He had seen quantities of ten, twelve, and twenty pounds of gun-cotton burnt away in the open air with perfect security. But there was one fact which remained, that poor Mr. Edward Prentice was blown to pieces—absolutely blown to pieces—by two boxes of gun-cotton on the open turf—neither in a magazine, nor under a shed, but on the turf. He wished particularly to urge upon every one that gun-cotton, at ordinary temperatures, such as 60°, 70°, 80°, perhaps even up to 90° Fahr., might be safely used and stored; but when the temperature exceeded 100°, as on hot days in the summer, he had the strongest opinion that an explosion was imminent, and that either vibration, blows, or any other accessory to that condition in which it then was, might cause it to explode. He did not agree that it was impure gun-cotton at Stowmarket; neither did he believe that, bad as some of those samples were, the sulphuric acid that was present was the cause of the explosion. He ignored that theory altogether, and believed it was utterly and entirely impossible for any sulphuric acid to have been added to that gun-cotton at Stowmarket designedly, maliciously, or accidentally. He drew that conclusion from a very careful study of the whole case. He attended the inquest, and heard every word that was spoken there. Not satisfied with the conclusions he himself most carefully had drawn, he revisited the works, and spent three days in studying the ground in every possible way. The works formed the letter L; and the long shaft of the L was separated from the other part by a river. All the acid work was done on one side, and all the finishing on the other; and no acid could be taken from its own side to the other without being where it ought not to be, and where persons employed and everybody interested in the work must have asked, as it was passing: "Why is this sulphuric acid being taken there?" He thought a considerable portion might have got into that part of the works; by reason of that portion of the material containing it being heavier than the rest in the poachers and the tanks, it might have settled at the bottom. But what was required with regard to gun-cotton at the present moment was a thorough investigation as to its carriage and storage in large quantities. It was not sufficient to pile up a box or two, and to put a few timbers on them, and cover them with earth, in a cool temperature. Safety demanded that those experiments should be tried at the hottest time of summer. Admitting all that had been said with regard to its dangerous use in mines, he (Mr. Mackie) must say of gun-cotton that it was the cleanest substance to use for military engineering works. It was most effective for open-air operations; and it had the advantage that troops might carry it to considerable distances without any fear. In case of an explosive bullet being sent into a mass of it which was being carried, it would simply set fire to the gun-cotton; and the man would have time to drop it. The same argument, however, applied to cartridges of nitro-glycerine compounds. As regarded the question of their safety, especially with respect to transport and storage, searching experiments ought to be carried out to settle both those points. When Mr. Nobel experimented with his dynamite in 1868 at Merstham, he (Mr. Mackie) was exceedingly pleased with everything that was done. But no experiments were made with regard to safety in transit; and he suggested to Mr. Nobel that he should make such an experiment, in order to satisfy the public. The question of its safety in storage also was not proved; and therefore he (Mr. Mackie) was not satisfied in his own mind. There was an absence of proof, though there was no proof to the contrary. With regard to lithofracteur, he was present at the trials that were made at Mr. France's quarries; and he did not hesitate to say that no similar material had ever been put to a severer test than lithofracteur was on that occasion. The effect on the quarries was certainly very remarkable. It was placed in bore-holes in the floor of the quarry, of an immensely hard dense greenstone rock; and it lifted so much of the rock by its force, that upwards of forty tons were displaced.

Captain Harvey had dwelt upon a very important point, and that was the necessity of a proper explosive for torpedoes. He had defined the two main requirements most clearly. For torpedoes an explosive was required which would fire under water, not being subject to injury by damp, and not liable to explosion in storage, but which could be carried in ships with perfect safety. With regard to Captain Harvey's torpedoes, any explosive could be used, as far as efficiency was concerned, because even in the case of gun-cotton, which if subjected to a large amount of damp would not explode in a torpedo, still for the short time that a torpedo would be stationary in the water, gun-cotton might be used with effect. But if one of the torpedoes exploded in a ship, it would do quite as much harm to the ship as if one went off underneath it; and one of Captain Harvey's large torpedoes would effectually settle a very large vessel. Considering the heat of the engine-room, and other places with which the stowage would be connected, it was very essential that the explosive used should be a stable one.

Mr. W. Matthews said he had recently witnessed some experiments at St. Heliers, Jersey, bearing upon the subject of the paper. Mr. Coode was engineer to some harbour works there, and he was desirous of ascertaining the relative merits of compressed gun-cotton and dynamite and lithofracteur. Unfortunately, through the difficulty of obtaining lithofracteur, they had to resort to gun-cotton only. They used about 70 lbs., and obtained excellent results. One blast was very remarkable. Twenty-five pounds of the compressed cotton were placed in three tins—two tins containing 10 lbs. each, and one containing 5 lbs. The gun-cotton was in discs 1½ inch thick, and the cases were about 2 inches in diameter. The three charges were fired by a battery simultaneously. The tins were placed in 8 feet of water, and when the charges were fired the explosion threw up an immense column of water and fine spray, mixed with stones, to a height of 100 feet. As near as could be judged, about 100 tons of rock were detached by that blast alone. The whole operation of charging the tins, greasing them, and giving them to the diver to take down and properly connect with the firing apparatus, occupied about half an hour. He (Mr. Matthews) quite agreed with what Mr. Webb said as to the slow combustion of gunpowder. The Americans had found the same defect in the combustion of gunpowder, and remedied it by the insertion of a string of fuzes, instead of having only one fuze in a blast of gunpowder, and by that means they obtained a more perfect combustion. Lithofracteur certainly possessed one great advantage over gun-cotton, and that was evident in the experiments to which he had referred. In one case a tin leaked, and the consequence was that the charge of gun-cotton was rendered useless. Had that been a charge of lithofracteur, such an accident could not have occurred. Another point was, that lithofracteur admitted of water tamping being used, which was a very important advantage.

The PRESIDENT observed that the time for closing the meeting had arrived; but as there were several gentlemen desirous of speaking on the subject of the paper, the discussion would stand adjourned until the next meeting. Before adjourning, however, he would ask Mr. Nursey, to reply to the discussion that had already taken place.

Mr. NURSEY, in replying to the observations which had fallen from various speakers during the evening, said he would first refer to the remarks made by Mr. France with regard to gunpowder firing upwards. It was because it was coarse grained, and consequently very slow in combustion as compared with fine-grained powder. He (Mr. Nursey) had frequently picked up grains of pellet and other large-grained powder from the front of heavy guns at Shoeburyness, showing that the powder burned so slowly that the whole charge had not time to ignite, but was partially blown away unconsumed. With gun-cotton, lithofracteur, and dynamite, the combustion was so extremely rapid that the effect was highly intensified local action. In using gunpowder, however, for blasting, a tamping of sand would be found advantageous in confining or resisting the force of the explosion, and in a case of miss-fire it could be removed much more easily than tamping which consisted of *débris* of the workings. He thoroughly agreed with the remark, that all explosive compounds ought to be treated as dangerous. In his paper he had only assigned to them a relative degree of safety, such as had been proved by experiments, but practically they should be treated as dangerous. With regard to the relative safety of dynamite and lithofracteur, he could only repeat what he had stated in his paper. Until dynamite had been tested under precisely the same conditions as lithofracteur, no one had a right to assume that they were equally safe. Lithofracteur had been tested under extreme conditions of danger, and had stood the test; dynamite had not been so tried, and therefore its safety was more or less assumptive. But as a matter of fact, dynamite was found to be practically safe under all ordinary conditions, and would probably be found capable of standing tests as severe as those he had applied to lithofracteur. With regard to the production of glycerine, he was aware that it was manufactured from animal substances, but he was also under the strong impression that it was originally obtained from coal, and was still produced from vegetable substances. That was why he had placed it in the category of vegetable products, and hence his reason for suggesting that research should be directed to the base of gun-cotton,—a vegetable base,—as it had been to the base of dynamite and lithofracteur, which, as far as the glycerine went, he still believed would be found to be a vegetable base. With regard to the main question, the use of violent explosives, there was no doubt that engineers, quarry proprietors, and mine owners were greatly desiring a powerful and safe explosive, and it was to be hoped that the production of such compounds as lithofracteur and dynamite would lead to a modification or relaxation of the more stringent clauses of the Nitro-glycerine Act.

November 6*th*, 1871.

BALDWIN LATHAM, PRESIDENT, IN THE CHAIR.

RECENT IMPROVEMENTS IN EXPLOSIVE COMPOUNDS.

ADJOURNED DISCUSSION.

The PRESIDENT informed the meeting that Mr. Nursey, having been suddenly called away from London, was unable to be present at the meeting, but had forwarded the following communication upon the subject of his paper, which was then read by the Secretary.

17, GREAT GEORGE STREET, WESTMINSTER,
2*nd November*, 1871.

DEAR SIR,

Having to proceed to the north of Ireland on business which will detain me there for a week or more, I am obliged to be absent from the meeting of the Society, on the 6th instant, at which my paper on Explosive Compounds is to be further discussed. I must therefore ask you to excuse my absence, and to receive by communication the few remarks I had proposed to offer verbally by way of re-opening the discussion.

Bearing in mind the object of the paper, which was to give an account of recent improvements in the development of explosive compounds, applicable to engineering and other industrial purposes, and, as it were, in continuation of that subject, I would first draw the attention of the meeting to one or two matters which have come under my notice since my paper was read. About three weeks since a paragraph appeared in 'The Times,' referring to a new explosive. It was as follows:—"Our Berlin correspondent mentions that Captain Bjorkman, of the Swedish service, has invented a powerful explosive, requiring no resistance to bring out its destructive force. Experiments tried in the neighbourhood of Stockholm prove that a cartridge about an ounce in weight will penetrate an iron plate half an inch thick upon which it is placed." I have not been able from inquiry to ascertain what this new explosive is. My own opinion on the subject, however, is that it is nothing more than dynamite, inasmuch as at Stockholm there is a manufactory of that material.

In the next place, there have been some experiments with gadoxylin, which is said to be a new preparation of gun-cotton. It is the invention of Mr. Davenport, a chemist of Wolverhampton, and the inventor of the magnesium shells. This explosive is stated to be both safe and powerful. A small portion was hammered into powder on an anvil without any explosion taking place. Some of the material was then placed in an iron vessel, and held over a fire until the vessel was highly heated, the result being that the gun-cotton disappeared without igniting. A small portion was next exposed to flame, when the combustion was so rapid as to cause a shock in the atmosphere, thus testifying to its great propulsive force. This violence of action under the conditions of ordinary ignition, however, appears to me to be fatal to the success of the invention, inasmuch as there would be no immunity from violent explosion were it to take fire.

Although not exactly a novelty, it may nevertheless prove interesting if I offer a few remarks respecting gunpowder compressed according to a method devised by Captain J. Harcourt Brown, in 1859. Some samples of this material have come into my possession since my paper was read, and I have been favoured with particulars respecting it by Mr. Orlando Webb, of Bangor. Captain Brown's invention consisted in compressing gunpowder into cakes or charges, which were suitable for heavy guns as well as for small arms, the charges fitting the bores. The powder was compressed without destroying the granulation or injuring the explosive quality of the powder. To accomplish this he used a solution of spirit, containing an admixture of gummy matter, which he spread over plates or cylinders, and then sprinkled the powder into it so as to allow the grains to adhere thereto, and each grain to imbibe a small portion of the solution. The powder was afterwards scraped from the plates, and deposited in moulds of the required diameter and normal length, and compressed by machinery so as to reduce the length of the charge about 2-7ths. The advantages resulting were, that the flannel-bag ordinarily used for holding the charge of powder for large guns was dispensed with, and the compressed charge was introduced into the gun without any case or covering. The reduction of the length of the charge and doing away with the flannel-bag, enabled the projectile to be carried lower down the gun. The whole of the powder was consumed without any portion of it being blown out of the gun without undergoing ignition, as is commonly the case in firing heavy guns with loose grains.

The result of experiments made in 1860, with Whitworth 1, 3, and 12 pounder guns, at different elevations of 1, 5, and 10 degrees, with this powder, is stated to have proved most satisfactory. In each case the range attained with the compressed charge was about one-fifth greater than with the same weight of powder taken from the same cask, and fired in loose grains in the ordinary way. Experiments were also made at Shorncliffe, with the Enfield rifle, under the superintendence of General Hay, and it was found that the compressed charge required a lower trajectory to carry a bullet the same distance—say 600 yards—than was necessary with the same weight of ordinary powder in loose grains. The attention of the authorities was drawn to the advantages of this invention, but no steps appear to have been taken towards its practical introduction into the service.

It may be satisfactory to note that the 35-ton gun has been further tried since the date of my paper with continued good results. It has been bored out to a calibre of 12 inches—the previous calibre being 11·6 inches. This enlargement of the bore has of course shortened the length of the powder charge; and it appears that the whole of the charges now used—which are 115 lbs.—are consumed in the bore. The pressures are found to be reduced to about 25 tons per square inch, with velocities of about 1300 feet, Waltham Abbey large grain pebble powder being used. So far these results are all very well; but when the gun comes to be tried for range and accuracy, I think its performances will fall below the proper standard. The enlargement of the bore of course necessitates the shortening of the projectile, to keep it within the prescribed weight of 700 lbs., and the consequent enlarging of its diameter. The results will doubtless be unsteadiness in flight, with a reduction of velocity, owing to the pressure of the atmosphere on an increased area of surface. This will involve a reduction in penetrative power; besides which a larger projectile will have more work to do in punching its way into the plate than one of smaller diameter, other things being equal. We have therefore yet to learn that the 12-inch 35-ton gun will be an effective weapon when set to do the work required of it.

Seeing the demand for a safe yet violent explosive compound, as pointed out in my paper, I deem it a matter for congratulation to find that, at the request of the Home Secretary, the War Office has appointed a special committee to inquire into the safety and properties of lithofracteur, dynamite, gun-cotton, and other explosives, with reference to their importation, manufacture, storage, transport, and use. The committee, which consists of military and naval officers, a chemist, a civil engineer, and a mining engineer, have already held one sitting, and it is to be hoped that the question will now receive the attention it merits, and that the increasing demands of engineers and others for a serviceable explosive compound will in course of time be met.

I would conclude these remarks with a reference to a question which arose at our last discussion upon the subject of glycerine. It will be remembered that in my paper I referred to the nitro-glycerine in dynamite, and the cotton in gun-cotton, as both being of vegetable origin, and suggested a course of inquiry into their natures, with a view of possibly treating the cotton for safety in a similar manner to that adopted with nitro-glycerine. It was at the last meeting questioned whether glycerine was a vegetable product, the general opinion being that it was derived from the animal kingdom. My impressions were strongly in favour of its being a vegetable product, and I find that I am right, inasmuch as it is largely, and in fact was originally, produced from palm oil, some thousands of tons per annum being made. It is also quite true that it is an animal product, being also made largely from animal fats and oils. But here I hold—not for the sake of argument so much as the suggestion of fancy—that glycerine is still derived from the vegetable kingdom, its origin lying in the herbaceous food consumed by the animals. But this in passing. I was only desirous to point out the exact foundation for my statement that glycerine was a vegetable base.

I trust these few hasty remarks, together with my paper—a copy of which has been sent to each member—will afford matter for an interesting discussion, in which I much regret I shall be unable to take part.

I remain, dear Sir,
Yours faithfully,
PERRY F. NURSEY.

TO THE PRESIDENT OF THE
SOCIETY OF ENGINEERS.

Mr. KERSHAW asked what was the cost of dynamite and lithofracteur, and where it was to be obtained. He found that there was great difficulty now in procuring them, although there was a large demand for them, which it appeared impossible to satisfy, owing to the legislative enactments consequent upon the recent explosions of nitro-glycerine.

Mr. CARGILL said that lithofracteur could not be obtained in England, although it had for some years past been extensively used in Germany. The Nitro-glycerine Act was an effectual bar to it and similar compounds, although it was hoped that the Act would be relaxed in its favour if its safety could be proved to the satisfaction of the Government. Of its explosive effect as well as of its safety he had had abundant proof, and he considered it to be a very valuable explosive compound, but as yet there was a difficulty in England of introducing it. There was no question but that in practice it would prove to be a great deal cheaper than any explosive hitherto available for blasting purposes.

Mr. Vallance said that he agreed with what Mr. Nursey had said at the last meeting as to glycerine being obtained from vegetable products. Since the meeting he had gone into the matter, and he had found that glycerine was obtained from vegetable as well as from animal substances. Glycerine was at one time a waste product in the manufacture of palm oil, stearine, and other substances, but which had become valuable from the various applications which had been found for it.

Mr. Orlando Webb said that, in his opinion, sulphuric and nitric acids had a very peculiar effect on vegetable fibre. They had also a very extraordinary effect on fatty matter, and that when the two were combined with glycerine a much safer article was obtained than when they were combined with vegetable fibre. He was quite satisfied, after a careful examination of the events which took place in connection with the Stowmarket explosion, that it arose from the solar heat and from spontaneous combustion. A very remarkable circumstance connected with that explosion was, that two days previously to the event taking place Professor Engels, who had given more attention to gun-cotton and other explosives than perhaps any other man in the world, stated most distinctly, that in the then state of the atmosphere he considered the collection of gun-cotton at Stowmarket to be most dangerous, and that it was liable to explode. Singularly enough an explosion did take place within two days from the statement being made. There was another matter connected with the preparation of gun-cotton which appeared very extraordinary. Cotton itself, under certain circumstances, when collected in large quantities, was liable to spontaneous combustion. Nitric and sulphuric acids had a very extraordinary effect upon vegetable fibre, and especially upon cotton, and after cotton had been soaked in those acids for a length of time very great trouble was taken, and every possible means adopted, to wash out and get rid of those acids, and it was presumed that by the processes used—beating it up and washing it for many hours with every care and attention in running streams, and so forth—the acid was completely got rid of. It was, however, quite clear that it was not. The effect of the acids remained. If it did not remain it would be cotton, and not gun-cotton. It therefore appeared to him (Mr. Webb) to follow that if cotton itself, in large quantities, was liable to spontaneous combustion, gun-cotton was much more liable.

With reference to the remarks which occurred in Mr.

Nursey's communication, read that evening, relative to the invention of Captain John Harcourt Brown, he (Mr. Webb) had witnessed some experiments which were made with it, and which went to prove that compressed powder, both for large guns and for small arms, was a most valuable invention.

Mr. CHURCH said that the principal practical question of the paper was, whether violent explosive compounds could be so manufactured as to be free from liability to spontaneous combustion. On that their value entirely depended. He agreed with Mr. Webb that the explosion at Stowmarket arose from spontaneous combustion, resulting from excessive solar heat. But it was also tolerably certain that the cotton had been damaged either by accident or design, by having an excess of acid, and where there was an excess of acid the cotton, from any excess of temperature, would be subject to spontaneous combustion. About a month before the explosion he (Mr. Church) went through the works and saw the whole process, and it appeared to him to be very carefully carried out, and both in the mechanical arrangements and the chemical department there was every care exercised. As far as a casual visit gave him an opportunity of judging, it appeared to him that if the manufacture was properly carried out the evil results which had arisen would not occur in the ordinary way. As to cotton itself being subject to spontaneous combustion, there was not much in that, because cotton waste, if packed in any great quantity, and in a damp state, was subject to spontaneous combustion, but not otherwise. He had never known a case of cotton waste being subject to spontaneous combustion unless it was in a damp state. Now that quality was not confined to cotton alone. In coal the same thing was found; there was the same element—carbon. If coal was packed in large quantities, and was damp, it was subject to spontaneous combustion, and many cases of spontaneous combustion had arisen from that circumstance. Carbonaceous matter packed in large quantities in a damp state was subject to spontaneous combustion. But the statement that, because cotton was subject to spontaneous combustion, gun-cotton must necessarily be so, would not apply, because in the process of the manufacture of gun-cotton the cotton was thoroughly dried. It was also compressed and every care was taken to bring it into such a condition that it was not subject to the ordinary conditions that cotton would be in order to produce spontaneous combustion. The gist of the question was whether we were in a position to manufacture those explosive compounds in a perfectly safe manner. He would not place nitro-glycerine in the same category as gun-cotton, because he did not think from his experience of nitro-glycerine, that it would explode from spontaneous combustion, but it exploded from concussion, and very small concussion would produce a very great effect. For mining purposes the violent explosive compounds were of the greatest possible value, and there should be no impatience in the development of them, but each should aid as far as possible to perfect their manufacture. If they could be produced in such a way as to be free from spontaneous combustion or other element of danger, they would prove highly valuable in the arts both of peace and war.

Mr. JACOB said that one speaker seemed to infer that the manufacture of gun-cotton was a chemical combination of sulphuric acid and nitric acid with the cotton, or of either separately. Such was not the case. It was a chemical combination of nitric acid with cotton, and the addition of the sulphuric acid was simply made to remove all the superfluous water from the nitric acid, as it was very difficult to procure nitric acid of a sufficient specific gravity for the manufacture of gun-cotton without the addition of sulphuric acid to deprive it of its water. Sulphuric acid had a strong affinity for water. The great difficulty in the manufacture of gun-cotton was the complete removal of all the acids, both nitric and sulphuric; and if that had not been accomplished the cotton would be subject to decomposition. It had been inferred with some show of reason, that that was the cause of the explosion at Stowmarket; but he had heard that the explosion really took place from an accidental introduction of a quantity of cotton which had been subjected to the acid process without being properly washed.

The PRESIDENT inquired whether anyone present had had any experience as to the nature of the gases which were evolved in the explosion of the nitro-glycerine compounds—whether they were found to be deleterious.

Mr. WEBB said that there was no doubt about that. Nitro-glycerine was a poisonous compound, and gave off a disagreeable gas; but there was a curious circumstance attending its use, and that was the more it was used the less effect it had. Mr. Nobel had compared it to sea-sickness, or wine. If a man took several glasses of wine he was not accustomed to, it had an extraordinary effect upon him, but if he was accustomed to it it would have no effect upon him, and the same thing happened with nitro-glycerine. In the manufacture of dynamite Mr. Nobel employed persons to mix the silica with the nitro-glycerine, and they preferred doing it with their hands. He (Mr. Webb) knew from experience that if anyone handled nitro-glycerine the skin acted as an absorbent, and the nitro-glycerine would act upon the system in a very short time. It produced a most extraordinary effect upon the men at Mr. Nobel's works. On the first occasion a violent sickness resulted, something like sea-sickness, but after that the workmen threw it off completely, and it produced no bad effect whatever upon them. With regard to the fumes evolved in its explosion, it was a matter of fact that in the mines in Germany the general health of the men was certified to be better since they had used dynamite than it was previously when they used gunpowder. His own experience was that by exposing himself to the fumes for some few days, he becamed inured to them and felt no ill effect from them.

Mr. Cargill wished to know whether dynamite could be rammed down for mining purposes,—whether it would stand the shock of a ram in the same way that lithofracteur would. Also whether it would withstand the shock of impact, or was explosive. An explosive compound like dynamite had to be transported all over the world, and was therefore liable to all sorts of accidents —liable to come into collisions of all kinds between iron and iron, stone and stone, wood and wood, iron and wood, and so on. Its safety therefore depended altogether upon what bodies with which it came into violent contact would cause it to explode. That was a very important point, because in some experiments he had recently witnessed with lithofracteur in the mines near Shrewsbury, the explosive could be rammed down with almost any amount of violence, and Mr. Nursey had given in his paper a *résumé* of the various bodies with which it exploded when brought into violent contact. It would be interesting to know how far gun-cotton, dynamite, or lithofracteur, would safely resist such contact with various bodies.

Mr. Webb said he had not the opportunity of witnessing the experiments with lithofracteur, but whatever could be done with lithofracteur could be done also with dynamite. It could be rammed down with any amount of force, provided it was not rammed with iron against iron, and provided also that a sharp smart blow was not struck.

The President, in closing the discussion, observed that the question of a safe explosive was one of great importance to engineers who were interested in being able to obtain some such agent for the prosecution of various works. The object was to obtain a compound which should be powerful on the one hand, and not dangerous on the other. With regard to dynamite, he remembered some two years ago being at Dantzic in the winter, when the ice was two feet thick, and a rapid rise of the river Vistula was expected; dynamite was used to blow up the ice, and it blew it up very well, but it used to blind the workmen, and they had to resort to gunpowder. There were, therefore, some conditions under which dynamite might be used, but in which it was not successful. With regard to the nitric and sulphuric acids in gun-cotton, the sulphuric acid was merely used for the purpose of taking up the surplus water, and then the only acid that should remain would be in combination with the cotton, which could not be washed out. In fact, it had lost its nature as an acid, consequently after careful washing there was no reason why the process should not be satisfactory. But then there came the question whether that preparation of gun-cotton was such as to preserve it from decomposition. That was a moot point, because wherever decomposition took place, among the first products formed were nitric and nitrous acids, which entered largely into the results of decomposition. Consequently it was questionable whether or not nitric acid would preserve cotton from decomposition; and if it was liable to decomposition it would be liable to explosion. With regard to nitro-glycerine and the other compounds, although they were protected by being diluted with a large quantity of sand, as in dynamite, or by the admixture, as in lithofracteur, of other substances, in the present state of our knowledge great care ought to be exercised with regard to their use. With regard to the paper, the Society was much obliged to Mr. Nursey for the admirable way in which he had brought the subject before it.

December 4th, 1871.

C. J. LIGHT, VICE-PRESIDENT, IN THE CHAIR.

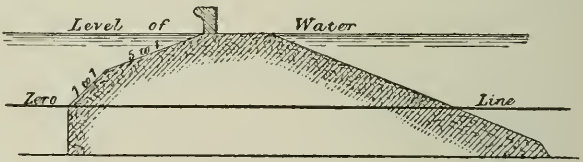
FLOATING BREAKWATERS.

By THOMAS CARGILL.

The subject which the author brings on the present occasion before the Society is one which, more than ten years ago, engaged the attention and consideration of a Select Committee of the House of Lords. The importance of the question was as fully recognized then by the Legislature as it probably is now, but notwithstanding the lapse of time which has intervened since the Committee terminated their labours, the whole matter has remained ever since in total abeyance. Not a single attempt has been made to ascertain if adequate shelter and protection for the shipping upon our coasts cannot be provided upon some less extravagant principle than that which involves the erection of costly structures of solid stonework. The unsheltered nature of our shores is a standing disgrace to us, as the first naval power in the world. It is notorious that the seaman fears the coast infinitely more than the open sea. Captains of packets and mail steamers have asserted in evidence, over and over again, that the "getting in and out of the harbours" is the source of more peril than the whole of the rest of the voyage, and it is but too well known that, owing to the same cause, thousands of our fishing and sea-going population earn their bread at the daily jeopardy of their lives. To endeavour to remedy this disastrous condition of affairs by the universal adoption of the only method which has been hitherto employed for the purpose, *viz.* that of solid structures of stone, would for many reasons be perfectly futile. In the first place, the excessive outlay attendant upon these works would be, and is, an insuperable obstacle to their general employment; and, in the second, there are numerous localities in which it would be practically impossible to construct them. Apart from other considerations, these two would alone be sufficient to justify the abandonment of the whole type of construction and a fair trial of the new. By the latter is signified the adoption of a different form of breakwater, and the substitution of a material different from that which has been hitherto almost exclusively employed. Iron may now be regarded as one of the principal constructive materials at the disposal of engineers, and it is not too much to assert that there are few examples demanding their skill and attention to which it is not capable of being applied with advantage. In bringing forward to your notice the claims of iron floating breakwaters, as well calculated to afford all the shelter and protection necessary to the welfare of our commerce and the safety of our ships and sailors, the author must unavoidably take a brief review of the similar solid structures that have been already erected with the same object in view, otherwise it would be impossible to institute a fair and impartial comparison into their respective merits and demerits. Before, however, entering thus far into the subject, there is a preliminary feature in it which is of the greatest importance, which should be first considered, *viz.* the action of the waves. It is the more requisite to take this point into the fullest consideration, inasmuch as an accurate and clear comprehension of the nature and theory of wave motion is absolutely indispensable in order to design a floating breakwater which shall be able to do its duty. Moreover, many persons possessing undoubted claims to scientific and professional knowledge most unaccountably entertain very erroneous opinions respecting the theory of waves.

The origin of waves is due to the action of the wind over an exposed surface of water. There are many varieties of waves, but the two which have more immediate bearing on our subject than the others are those called waves of oscillation and waves of translation. It is in the confounding of these two that has arisen such serious misunderstanding. In comparatively deep water a wave consists of a series of successive undulations, which start, rise, culminate, fall, and finally come to rest. These undulations, or oscillations, impart an appearance of a progressive motion in the watery mass which does not in reality exist. A person standing on the shore and watching any particular wave out at sea will be under the impression that it is advancing towards him with great velocity, and probably will imagine that that identical wave at last rolls on the strand at his feet. That idea is completely delusive. The range of motion, in a progressive sense, of the particles of the wave which he may have singled out is very limited. It would be practically of little use to inquire into the various hypotheses which have been put forward to account for the action or origin of the undulation. It has been stated to be due to the motion of the particles of water in an elliptical or circular orbit, and that this peculiar path in which they move results from the two forces which govern their movement, the one being gravity, and the other the wind, or whatever disturbing cause may act in its stead. However this may be, the important fact to be borne in mind in connection with floating breakwaters is that undulatory, or oscillatory waves, have no sensible progressive nor percussive action. That motion exists there is no question, but it is motion without transference of matter. The motion is communicated progressively, but the particles of water after their brief agitation remain at rest. The next point to be considered with regard to waves is the range of their action, or the depth to which their influence extends, and is a very important one in connection with the subject of the present paper. In fact, the whole theory of floating breakwaters hinges upon the fact that the influence of waves practically ceases at a certain depth below the surface. Experiments have fully established this fact during the construction of solid breakwaters, lighthouses, and other marine engineering works. The testimony of divers engaged on wrecks is to the same effect. They have found that they could pursue their work with equal facility whether a storm was raging over their heads or the surface of the water in a perfect calm. The rapidity with which the disturbing action of waves diminishes as the depth increases is very remarkable. At a depth of about 10 feet below the surface the movement is only $\frac{1}{500}$ of that which it is at the surface, and as the decrease proceeds in geometrical progression a depth is speedily reached at which the disturbance is practically *nil*. In other words, we shall arrive at what may be termed the plane of no motion. This plane is represented in Fig. 1 by the thick black line which

Fig 1.



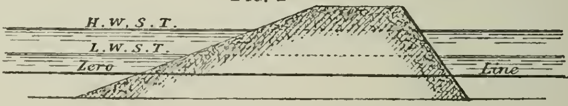
may be called the zero line. This figure shows the form of a normal breakwater, or the form which the materials, such as loose stone, would assume if acted upon by no other forces than that of the water and of gravity. It will be seen that as the material is carried lower and lower down the transporting power becomes less and less; so that while in the first instance they take the form of a long flat slope of about 5 to 7 feet, they subsequently assume that of about one to one, and finally terminate vertically. The depth at which the influence of the waves ceases has been put at from 12 feet to 15 feet. Let us take the latter value, and therefore the zero line, or plane of no motion, will be situated at a constant depth below the surface of low water of 15 feet.

The next description of waves with which we are concerned are those of translation. These may again be divided into two classes. The first are those which are generated by tidal and marine currents, which frequently possess considerable velocity, but have no appreciable percussive action. The transporting power of these waves is sometimes very great, but their impactive force is of little or no consequence. Under the second category are included those waves of translation which were originally waves of oscillation, but owing to certain circumstances, which will be alluded to, are converted from the former into the latter. Briefly, waves of undulation belong to deep water, and waves of translation to shallow. A breaker is a true wave of translation, and is only found in comparatively shallow water. Its origin is as follows:—When the water shoals, the motion becomes impeded in consequence of the greater degree of friction set up, which more particularly affects the lower portion of the wave. This part, therefore, is retarded, while the same cause does not operate upon the upper part, which retains its original velocity. The effect, therefore, of the wave being checked below and unimpeded at top, is to propel the upper portion forward, which finally takes the form of a breaker, and dashes, sometimes with tremendous force, upon an exposed coast. It is evidently not necessary that a natural coast or strand should exist, in order to give rise to the formation of a breaker. Any obstacle which causes a gradual shoaling of the water will effect the same purpose. In tolerably deep water it would be impossible for a breaker to form against a vertical surface, whether it be natural or artificial. It would always remain a wave of oscillation and never pass into one of translation. The importance of this fact, in connection with floating breakwaters, will be apparent as we proceed. It constitutes, moreover, theoretically, the great argument of those who advocate the vertical wall system of solid breakwaters, instead of the *pierre perdue*, or long slope principle. Into this argument there is no necessity to enter, more especially as it has been pretty well settled in favour of the vertical wall method. But it will be indispensable to make a general reference to solid breakwaters, in order to point out some of their defects which are remedied in the floating structure.

A very remarkable instance of the non-action of waves against vertical bodies, or those in which the horizontal dimensions are small compared to the vertical, was afforded by the timber staging designed by Mr. Rendel for the works at Portland, in which all the horizontal surfaces were kept above the action of the waves. The framing was wholly vertical up to the level of 15 feet above high-water mark, and there is no doubt the success of the stage was due to the observance of this precaution, and a knowledge of the true effect of waves. It has also been observed at Portland, that when the waves meet the circular heads of the passage between the two breakwaters, which consist of vertical walls, 24 feet below the level of low-water mark, they rise and fall in a perfectly gentle manner, while some 200 yards off, where the long slope occurs, the sea runs up and down with great violence and fury. The explanation is very simple. In the one case the water is deep, in the other shallow, so that the former has only to deal with waves of undulation, while the latter is exposed to the force of those of translation. Whenever a wave of translation dashes upon any inclined surface, it is not the transporting power that is chiefly to be feared, either in advancing or retreating, but the percussive force. It has been deduced by Mr. Scott Russell, from actual experiment, that a wave of oscillation will become converted into one of translation when the height of the wave equals the depth of the water.

The diagrams Figs. 2, 3, and 4, referring to solid breakwaters, are not intended to do more than represent their general outlines in cross-section, the object being to point out the position of the zero line, or plane of no motion, with respect to the mass of the structure. From what has been already stated, it will be seen that the transporting power or disturbing force of the water is comparatively superficial, and ceases at the depth of 12 feet or 15 feet below the surface, and it is therefore manifest that the portion of the solid breakwaters which extends below the zero line is not required for the mere purpose of protection or ensuring calm water to landward. It is certainly indispensable as the foundation of the superstructure that rests upon it; and, in order to show the quantity of material that must be used for this purpose, the relative areas of the parts above and below the zero line have been calculated. Commencing with the Plymouth breakwater, Fig. 2, the area of the section above the plane of no motion amounts to 6116 square feet, and below it to 5100 square feet, so that nearly twice the

Fig. 2



quantity of material is consumed than what is required to fulfil strictly the duty the breakwater has to perform. In the Dover breakwater, Fig. 3, which is built on the vertical principle, the relative proportions are very similar to those of the former, being for the upper part 2944 square feet, and for the lower 2160 square feet. In the Holyhead breakwater, Fig. 4, there is no waste of material in this respect, as the plane of no motion is close to the ground line at the bottom. A glance at these sections will point out that if we could dispense with all that portion of these solid masses below the zero line, and at the same time retain the part above it, we should have the perfection of a breakwater, so far as economy is concerned. Ample protection against the violence of the sea would be obtained, without any superfluous expenditure of material in a position below the range of its action. A structure that will fulfil these conditions the author believes will be found in the design represented in Fig. 8, which will be fully described in the course of the paper.

Fig. 3.

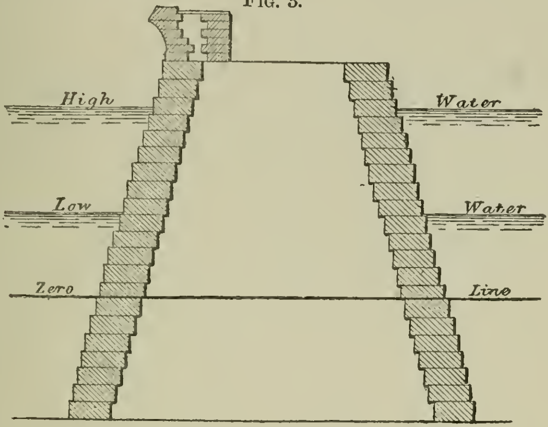
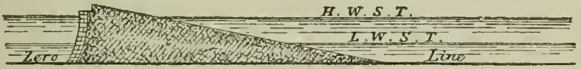


Fig. 4.

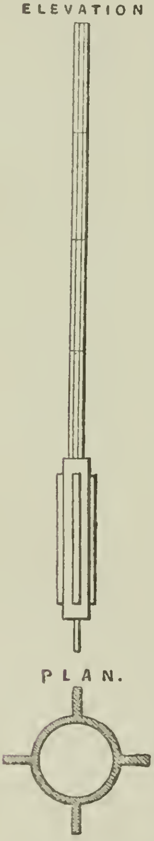


The expense of building a solid breakwater obviously increases enormously with the depth of the water; for assuming for the moment the rise and fall of the tide to be a constant, the upper portion extending from the top to the zero line will also be a constant, the variable quantity being the part below that line, which is a direct function of the depth of water. On the other hand, a floating breakwater, so far as the cost is concerned, is, under similar conditions, independent of the depth of the water, the variable quantity in this case being only the length of the mooring chains, which is a mere trifle. In addition to the two serious objections which have been universally acknowledged to prevail against solid breakwaters, namely, their great expense and the absolute impossibility of erecting them in certain localities where they are most urgently needed, there is a third which is of still greater importance. It is an indisputable fact that all solid breakwaters cause the accumulation of silt to such a degree that, after the lapse of a few years, they virtually defeat the very purpose they were intended to accomplish. It might be well asked, what is the use of building piers, harbours, and breakwaters on such a principle, that while they afford the protection needed, they practically prevent that protection being made use of by those requiring it? It is giving with one hand and taking away with the other. It may appear rather a bold assertion—but the observation has been made by eminent authorities before parliamentary committees—that all the money which has been spent upon solid breakwaters is just so much thrown away. That such is the truth with regard to a great many of them there can be no question, as they have either gone to pieces or been rendered worthless by the silting up and consequent shoaling of the water they were intended to preserve at its original depth. A few words respecting the cost of some of the most prominent of the solid breakwaters will terminate the notice of them. Referring to statistics we find that Portland cost 150*l.*, Alderney 190*l.*, Cherbourg 220*l.*, Plymouth 300*l.*, and Dover 415*l.* per foot run. The harbour of Howth, in Ireland, which was originally intended for a packet station, and is now only available for small fishing smacks, cost half a million of money, and the Plymouth breakwater requires an annual expenditure of 15,000*l.* to keep it in repair.

The first idea of a floating breakwater was probably derived from the observation of the effect produced on the waves by the presence of some natural obstacle in the sea, such as reeds and seaweed; and this idea was subsequently confirmed when the resources of art were called in to imitate the operations of nature. As an instance of a natural floating breakwater may be mentioned the seaweed botanically termed *Laminaria Buxinalis.* The lower part of this plant is attached to the rock below at a depth of 25 ft. or 30 ft., while the upper floats on the surface of the water. The gulf weed furnishes another example of a natural floating breakwater. It has been found that, although the depth of this weed does not exceed a couple of feet, yet, even in strong gales, there is perfectly calm water to leeward of it. The effect of pouring oil on a troubled sea has passed into a proverb, and the experience of nautical men has demonstrated over and over again that by mooring a number of floating spars to seaward of a small craft she can ride out in safety a gale which, without such protection, would infallibly swamp her. No sooner was the principle once recognized, that an adequate and secure breakwater could be constructed of open work, and that it need extend but to a comparatively small depth beneath the surface of the water, than a number of designs were put forward with pretensions towards fulfilling the object in view. The majority of these designs were feeble and impracticable to the last degree. To this cause must be attributed, in some measure, the circumstance that no tangible results followed the labours of the Select Committee of the House of Lords appointed to inquire into the subject of breakwaters ten years ago. It is more than probable that had any design of a floating breakwater been brought before the notice of the members of the Committee which gave any hope of efficiently fulfilling the duty demanded of it, they would have taken it into favourable consideration. Had any design been possessed of sufficient merit to warrant even a trial of it, the Government was prepared to grant 10,000*l.* towards the experiment, but it must be acknowledged that, with the examples before them, the members of the Committee would not have been justified in recommending the expenditure of such a sum. In some few of these designs the principle is very imperfectly displayed, and in others it is exceedingly badly carried out in practice. The fault of all the attempts hitherto made to construct floating breakwaters is that the designs, with one or two exceptions, have all emanated from unprofessional men. Consequently, notwithstanding that many of the designers were men well calculated to appreciate the principle and its value, they were perfectly in the dark respecting the method of putting it into practical execution. While understanding the theory, they were ignorant of the practice. That the question of substituting floating breakwaters for the more costly solid erections is not very recent may be inferred from the fact that in the year 1811, when plans were offered in competition for the Plymouth breakwater, Sir Samuel Bentham proposed to construct one there of timber on the floating principle. It was to consist of a number of wooden floats of a prismatic form, about 30 ft. broad and 20 ft. deep, held in their places by means of iron chains. In his report to the navy Sir Samuel Bentham observes that breakwaters such as these would not only leave the whole of the waterway uninterruptedly below them, but would also allow a great part of the tide to pass through them. They might, therefore, be extended all across the entrance, so as to afford protection to the whole of the Sound within it, leaving only in certain parts sufficient intervals between the rows of floats, as well as between the contiguous rows, to allow ships to pass. In the event of a ship striking against, or even running over one of these breakwaters, it would not be likely that such an accident would occasion any material injury to the ship any more than to the breakwater. A further advantage of these breakwaters, which may be considered of no small importance, is that no injury can accrue to any harbour from the employment of them. They may be tried in different parts of the harbour till experience shall have pointed out the most advantageous situation for them, or they may be entirely removed and employed elsewhere when circumstances render it desirable. It is obvious that these remarks apply with equal force to all floating breakwaters, but not to those of a fixed kind, whether they be built on the open or solid principle, since their foundations or supports must extend to the bottom, at whatever depth that may be.

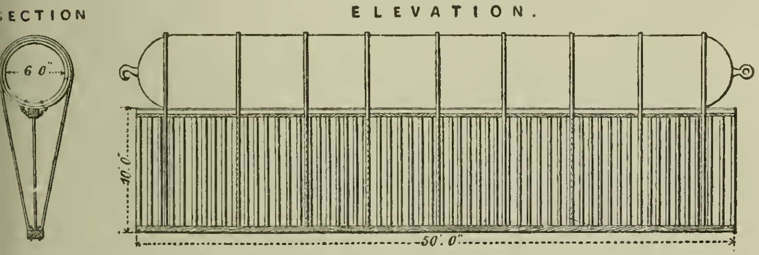
Two of the most noticeable timber breakwaters, which appeared early in the field, are those of Admiral Taylor and Captain Sleigh. The former was in the shape of a double prism, the lower one being deeper than the upper, and was laid down on the French coast between Toulon and Marseilles. That it did not answer its purpose is a well-known fact. The reason that it did not succeed is variously stated. Some assert that it was maliciously destroyed during the French Revolution; others, that it gradually fell to pieces of itself; and others again, that it was removed by order of the authorities as being useless as a protection to the shipping, and a nuisance besides. Captain Sleigh's breakwater is a solid one, insomuch as the only openings existing are those occurring between each separate section, the sections themselves being all water-tight. Like the former, the shape is defective, as the seaward face is based on the long slope principle. Upon the principle of reeds is founded the breakwater of Major Yule, represented in Fig. 5. The original design consisted of a number of poles floating

Fig. 5.



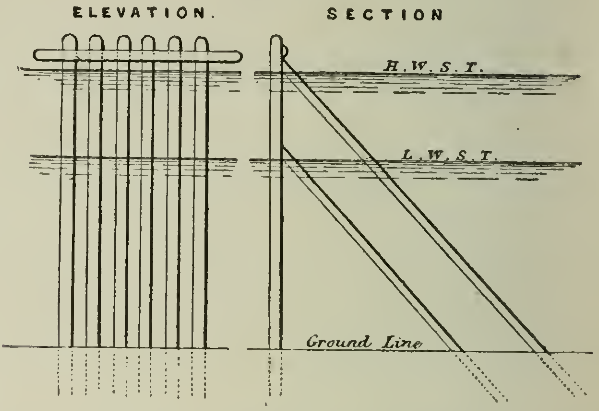
vertically, and fastened together at intervals of about 5 ft., constituting in reality a vertical floating boom. The drawing shows an amended design constructed of copper cylinders and iron leaves or blades. The cylinders are from 4 ft. to 6 ft. in length, with a diameter of 9 in. The leaves or blades which surmount them have open spaces between them, and are from 12 ft. to 20 ft. long, according to the depth of the water. They are secured together by iron wires passed round them every 3 ft. or 4 ft. in height. The idea of the inventor was, that the constant action of the sea through these leaves, by creating a variety of eddies, would lessen the force of the passing wave. This is one of the examples which displays a partial recognition of the true principle, but the practical application of it is utterly unsuitable to the requirements of the case. The arrangement of the details is such as would render it useless in the position of a floating breakwater in the proper sense of the term. In Fig. 6 is represented a floating breakwater invented by Major Groves. It consists of a large iron cylinder closed at both ends and floating horizontally, from the lower surface of which is suspended an iron rake for the purpose of combing the waves, and so preventing them from passing through *en masse*. It was tried and floated off Dover, but the first gale brought it ashore.

Fig. 6.



The enumeration of designs of fixed and floating open breakwaters would be incomplete were the wave screen of Mr. Calver to pass unnoticed. An elevation and section of it are shown in Fig. 7. It is composed of a number of vertical cylinders placed at a certain distance apart, the lower ends of which are secured to the ground. The cylinders are strutted on the land side by raking stays. The action is very similar to that of those already described, the undulations of the wave being supposed to be checked by the combined influence of the vertical cylinders and the open spaces between them. It partakes of the disadvantage of all fixed breakwaters which has been previously alluded to, namely, that the cylinders must extend to the full depth of the water, and the cost will therefore be in proportion. The practical inapplicability of single rows of cylinders to the purpose of a breakwater will be demonstrated hereafter.

Fig. 7.



Having reviewed the principal forms of fixed and floating open breakwaters which have appeared at different times, the author will now proceed to describe the example represented in Figs. 8, 9, and 10, and which was designed by the author and Mr. F. W. Bryant, C.E., to meet the views of the patentee, Mr. Robert Saunders. The theory of its action is based upon the principle that the force of the waves may be completely destroyed by presenting a series of individually small impediments to their violence. Gradually but effectually their influence is broken up and annihilated in detail, by the successive resistance it encounters, until the water reaches the landward side, or back of the breakwater, in a state of complete quiescence. Many of the floating breakwaters to which attention has been drawn in the present paper consist of a single file or series of screens. Theoretically one vertical screen in certain localities would be sufficient, but practically this is not generally the case. The breakwater must consist of a series of vertical screens, varying in number according to the nature of the coast and the character of the waves where it is moored. Otherwise, the undulations will not be sufficiently broken up or dispersed, but will either pass through unchecked, or re-form on the landward side, and then there will be little or no difference in the roughness of the sea, either inside or outside the barrier. It may be conceded then, that a series of vertical or diagonal screens, of sufficient strength and rigidity, and secure moorings, are the several essential features, the combination of which can alone constitute an efficient and safe floating breakwater. On referring to the plan, Fig. 8, and half-elevation, Fig. 9, it will be seen that the breakwater, which is composed partly of wrought iron and partly of timber, consists of a number of triangular-shaped frames (as shown in cross-section in Fig. 10) placed about 12 ft. 6 in. apart. The plan represents one entire section of the breakwater, 100 ft. in length, by 25 ft. in breadth by 15 ft. in depth. These dimensions are those which would generally apply, but are not intended to be adopted in every instance. The entire breakwater would consist of as many of these separate sections as the nature of the case might demand. The exact form of the whole would depend upon the physical contours of the coast. In some instances the ordinary form, consisting of a straight middle portion and two side spurs, similar to the Plymouth breakwater, would answer well. In others the crescent, or semi-lunar figure, would be preferable, while to meet the requirements of exceptional cases an irregular curve would be necessary. As an example of the last, the case might be taken in which one end of the breakwater was con-

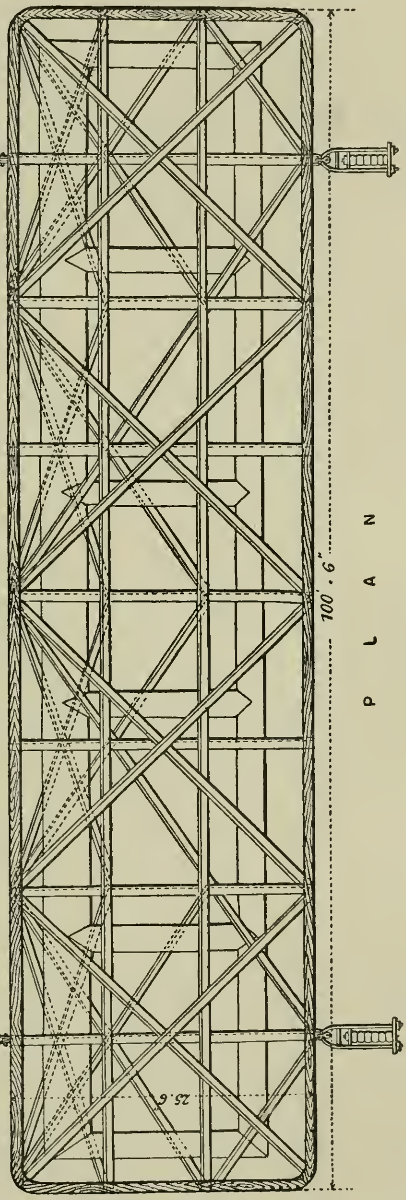


Fig. 8.

nected with the shore. The form would probably be that of straight line terminating in a curve. Although the length o the separate sections in the drawing is shown to be 100 ft., this, as wel as the other proportions, can be varied at pleasure. One of the cross-frames is shown in section in Fig. 10 It is constructed of strong tee and angle irons, the separate parts being all braced together, so as to form a rigid truss, at the same time that it permits the passage of the water through it in all directions. Each separate cross-frame is connected together by longitudinal ┬ and └ irons, and also interbraced by bars in horizontal, vertical, and diagonal planes, so that each separate length of 100 ft., or whatever other dimensions might be given to it, is equally strong in every part. The bars constituting the diagonal trusses are omitted to avoid confusing the drawing. The cross-section shows the series of three tiers of screens or louvre plates, 1, 2, 3, increasing in depth from the front to the back. These screens, which may be either of iron or wood, are arranged with intervals above and below them, so as to break joint in each successive tier. The flotation power is obtained by means of a cylindrical pontoon, the relative volume of which, on the seaward and landward face, is proportioned to the weight it has to support. The pontoon runs all round the breakwater, as seen on the plan, and there are, moreover, cross-pontoons connecting the two longest sides of it, which act in the double capacity of affording flotation power, and bracing the whole structure firmly together. The watertight floats or pontoons are divided at intervals by bulkheads or diaphragms, so that if by any accident, which is very impro-

FIG. 9.

ELEVATION.

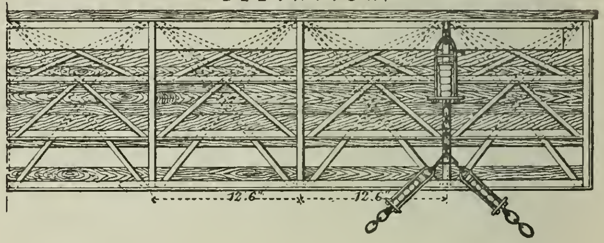
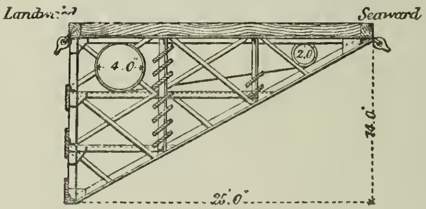


FIG. 10.

CROSS SECTION



bable, they should be stove in at any part, there would be no fear of the entire breakwater sinking in consequence. Besides, the floating power is so arranged as to leave a margin for these possible, though extremely unlikely, contingencies. The pontoons themselves also act as screens, as may be seen by inspecting the plan and elevation in Figs. 8 and 9. The one which is placed along the front of the breakwater renders a plate there unnecessary, and the same saving of material is effected by the other at the back. It is manifest that the disintegration of the wave, if the term may be used, is not only accomplished by the action of the screens, but by the whole structure itself, as owing to the openwork principle upon which it is built, it is exceedingly well calculated to promote the same object. There is very little doubt that in situations where the force of the waves was small, it would be quite destroyed by the bars of the framework alone, as the lattice character of the design is peculiarly well adapted to produce this effect. It would strain the waves, as it were, of all their force by degrees until they became perfectly harmless. But in other instances the gradual absorption of the wave can only be thoroughly brought about by a succession of vertical screens. The combination of vertical and inclined screens and lattice framework, as represented in the drawings, is perhaps adapted to afford the best results.

The next point to be considered with regard to floating breakwaters is the question of retaining them in the permanent position assigned to them, in other words, of mooring them. Much diversity of opinion exists and has been expressed on this subject, especially among engineers, who, as a rule, know little or nothing about the mooring of floating bodies at sea. This is one instance in which may be perceived the inconsistencies to which scientific men are sometimes liable. Many who have recognized the truth of the principle upon which all floating breakwaters are based, and expressed no doubt of their effecting their object, yet maintain that they would fail, and fail only because it would be found impossible to moor them. Now the fact is that if the truth of the principle be admitted upon which they act as floating breakwaters, it follows as a necessary consequence that, with proper precautions, there can be no difficulty in mooring them. In the example under notice the water is free to pass through the structure in every direction. Any progressive or transportive effort is at once met by a volume of still water, which forms a barrier against all such action. The idea which is prevalent among some—that floating breakwaters would part their moorings and come ashore in a heavy gale—is probably due to a variety of causes. One is, that proper consideration has not been given to the correct form and arrangement of the several parts of the breakwater; another, that it is argued analogically that because ships part their cables and get into difficulties, floating breakwaters must do the same. There is some excuse for this erroneous opinion being held by those who have never seen any other form of floating breakwater but the crude and imperfect examples belonging to the single-screen type. In the first place, these latter offer a sudden, instead of a gradual, resistance to the waves; and, secondly, the moorings which have been laid down in a few isolated instances were of the rudest and most inadequate description. The fallacy of the analogical argument against the mooring of floating breakwaters, founded upon the fact that ships break adrift, is at once apparent upon a little consideration. The two examples of floating bodies are entirely distinct, both in their construction and the manner in which they are affected by the waves. All ships have a tendency to what is nautically termed "to range." This, together with the jerk that frequently comes upon the cable, causes it to part. The breakwater in question is not liable to range, neither is it susceptible of those sudden jerks which are so destructive to ships' cables. But in order to provide for such a contingency, the moorings are designed to obviate all such danger. They consist of either chain cables or suspension links, to which are attached Saunders' patent buffer spring. The action of these springs, which are well known, is to disperse or absorb the momentum of any suddenly applied force, so that the shock or impactive violence is converted into a direct uniform tension on the cable. Without going into details, it may be briefly stated that the floating breakwater represented in the drawing can be constructed at a cost of less than one-tenth of the sum at which the cheapest solid breakwater can be built. In addition, therefore, to its other advantages, the floating breakwater possesses the great merit of economy, and is in every sense well adapted to afford in stormy weather access to the shore, shelter to the shipping, and safety to the sailor.

DISCUSSION.

The Vice-President in proposing a vote of thanks to Mr. Cargill for his paper, observed that the subject was one which had always been very attractive in many respects; although it had not been prominently brought forward in papers before scientific bodies, having been, as far as he was aware, alluded to only twice at the Institution of Civil Engineers, and on those occasions quite incidentally in discussions, and once when forming a very large part of a paper read before the Society of Engineers about twelve years ago. He believed those were almost the only occasions on which it had been prominently brought forward. At the same time it had always engaged the attention of men of ingenuity, with a view to overcoming the difficulties which had been met with, and the enormous expense which had been incurred in the case of fixed breakwaters.

Mr. Le Feuvre said that the author of the paper had stated that the cost of the floating breakwater was less than one-tenth that of the cheapest solid breakwater. It would be as well if the author could state the cost of the cheapest solid breakwater. He (Mr. Le Feuvre) doubted whether the buffer springs would give the required degree of elasticity, and he questioned whether they would be serviceable after twelve months' use in salt water. He thought the material, wrought iron, proposed by the author for the breakwater, was bad, it should be of cast iron and wood.

Mr. Pendred said, there was one point suggested by the paper, and that was the form assumed by breakwaters. It had been found by experience that in solid breakwaters the structure must invariably be allowed to take its own form. The form would depend upon the action of the waves, and upon the material used in making it. All the attempts that had been made to produce a breakwater to some peculiar curve or form, had proved futile. At the Holyhead breakwater attempts had been made to alter the contour of the external wall by tipping stones over the parapet, and endeavouring to make a foreshore at a certain point. It was a pretty wave curve that was to be arranged and built, but instead of that, the action of the waves had been such that in spite of all the tens of thousands of tons of stone that had been tipped over the wall, the breakwater had not assumed the desired form. It had been cut or eaten into by the corrosive action of the waves. It was an eroding action, more properly speaking; the stone was tipped in and accumulated in a heap to a certain height, and when a gale arose a heavy sea came in, and the stone was removed, and there was no approach to a curve at all; but there was an approach to a slope, of an indeterminate length. The erosive action appeared to be due to the waves coming in and turning over at the top. With regard to the floating breakwater, there was no question that by breaking up the action of the waves in detail, all the required results would be obtained. The mooring of breakwaters, however, was the great point, and it involved a consideration of the force exerted by the waves. That had been proved by Stephenson at one of the lighthouses he built, where he fixed a very ingenious arrangement of railway buffers, combined with a registering apparatus to test the power of the waves. The apparatus consisted of a disc, 1 square foot in area, upon which the sea acted. Connected with it was a buffer and a coiled spring. The exact distance to which the buffer had bee driven in by the force of the wave could be measured, and b testing the buffer and spring afterwards, the force exerted coul be ascertained. It was proved that the waves at times brough a force to bear something like 2 tons on the square foot. Takin the floating breakwater, and assuming that it was exposed to th action of the waves which struck it with the force of 2 tons t the square foot, very little strain might, by the local action o the waves in such a case, be brought upon the moorings. H did not apprehend that there would be very much difficulty i anchoring any breakwater of the kind, so that it would stan the force of the direct impact of the waves. With regard t the efficiency of the breakwater as a wave screen and as a mean for affording protection in the harbour, he had no doubt about i The inventor of the breakwater, Mr. Saunders, had also intr duced a very ingenious form of india-rubber spring, which ha been successfully used at Westminster Bridge, and had prove very efficient. It might be safely estimated that good india rubber would last well in sea-water for six or seven years. Tha would of course be a good quality of india-rubber, such as h had seen tested recently by Mr. Kirkaldy, and which woul stand without injury a strain of 60 tons to the square foot.

Mr. Jacob said he could understand that the springs woul afford valuable resistance to anything like a shock; but the poi which presented a difficulty to his mind was the arrangement the chains. The question was how were they to be arranged t allow of the action of the breakwater where there was a ver long range of tide between high and low water, especially whe they were subject to currents. Reed's breakwater appeared t be singularly ill-adapted to its purpose. There was one radic defect in its details, namely, the combination of iron and copp Such a combination could not last under water beyond a sho time. The galvanic action would at once prove destructi There was a point to which no allusion had been made in t paper, and that was the arrangement by which it was propos to float out the breakwaters from the shore. In many cases certain amount of shoal water had to be dealt with, and in th case it would be necessary to carry the masonry of the pe manent works into deep water before starting the floati breakwater.

Mr. Williams inquired the weight of one of the brea waters, and observed, with regard to the mooring of them, th he did not see much difficulty in it. Nautical men were ab to moor the 'Hercules' and the 'Great Eastern'; and th could surely manage to moor a light body like the floati breakwater.

Mr. **Houghton** considered that the author of the paper had done great service to the engineering profession and the public at large in bringing the subject of floating breakwaters before the Society. It was a subject of great importance; and it appeared to him (Mr. Houghton), from long observation, that it was the best design for a floating breakwater he had ever seen. It appeared to him, also, that the inventor had adopted the best material for the purpose, namely, wrought iron. There were two or three points, however, in which he did not agree with the author. He had stated that most harbours enclosed by solid breakwaters must silt up. His (Mr. Houghton's) experience was that Dover Harbour certainly did not silt up. The great difficulty in the neighbourhood of Dover was to prevent the shingle from going away. It was necessary to build groins, at great cost, to keep the shore in its position. The next point was the moorings; and having had long experience of rivers and sea, he could not see clearly how one of the enormous breakwaters under notice could be moored. The buffer of Mr. Saunders, no doubt, would relieve the strain very much upon the moorings. But, after all, there must be either screw piles or cables connecting the buffer with the breakwater; and that strain would be very great.

With regard to Mr. Pendred's observation as to solid breakwaters being constructed with one contour, and after awhile assuming another, that generally followed where the breakwater was built of rubble masonry, such as Holyhead, and several of the other breakwaters round the coast; but where the breakwaters were built of concrete blocks, the same as at Guernsey and Dover, there was no movement and no derangement.

Mr. **Halpin** said that previous speakers appeared to suppose hat the whole strain of the wave would come directly upon the buffers. He thought that would hardly be borne out, if the fact was remembered that in ships riding in heavy gales, with a great length of cable, the strain was very gradually brought on by the length of chain making a gradual approach to a straight ine. That formed a natural mooring; and only the last, and consequently the least, portion of the strain would come upon he buffer. With regard to the design of the breakwater, he would ask if the inventor had found any special advantage in he circular form of pontoon which he had adopted. Was here any objection to the pontoons being rectangular in cross-section? That form would greatly facilitate the manufacture. Another point was, whether the inventor had found any advantage in having the shields vertical. Would it not be better o have them placed at an incline? or, perhaps better still, to use a modification of Poncelet's bucket, and so make a curve, and destroy the oscillation of the water gradually, instead of breaking it suddenly.

Mr. Saunders said that, from what had fallen from various speakers during the discussion, it appeared that the success o the floating breakwater was considered as depending very muc upon the mooring. Ships being held by their cables had bee brought forward as a case for comparison. His work all his lif had been in connection with ships; and he maintained that n ship would ever break from her cable if proper mechanica means were used to prevent it. Ships would not break fro their cables if they could be kept tight astern of their anchor After a ship had been struck by a sea or a gust of wind, th cable was very tight, and the ship immediately had an impetu to go towards her anchor. The cable then became quite slac and the next sea or gust that came would drive her astern and it was a repetition of those shocks which broke the cabl With regard to the breakwater, however, if there was no tid no current, and let the wind blow as it would, and the sea ro as high as it might, the breakwater would never come to th shore, even if it had no moorings, because it was a body water itself. He had known instances in Mount's Bay, Cor wall, of ships cut adrift, and which had never touched th shore, but had floated some distance away from it. That wa owing to the under-current, which was really the back wave for after the wave had gone up an incline, the water returne back and built another wave, and thus the ship would be ke away from the shore. That was the action which went o and therefore the breakwater, from its peculiar constructio would never reach the shore, if it broke loose. But it coul never break loose if properly moored at all points in the fir instance, as proposed.

Mr. Jacob inquired the estimated cost of the floating brea water before the meeting. He would like to know what t author's calculations made the cost per foot run to be, inclusi of moorings, because that was one of the most important poin in the consideration of the subject.

Mr. Colyer said he had used india-rubber disc springs simil to those before the meeting in cranes, and had found the rubb to perish very quickly in the atmosphere, in some cases with a year; and he thought they would perish still more quickly sea-water.

Mr. Nursey said, with regard to the mooring springs th some four years since he had occasion to inquire into th merits for a professional purpose, and he was very well satisfi with what he then heard about them. They had been long use, and had been subjected to the action of sea-water for several years, and had given satisfaction. The india-rubber used by Mr. Colyer must have been a very bad rubber to perish in so short a time. The question of durability in that article—as in most others—was simply a question of quality, which again was a question of expense. There were rubbers in the market of very widely differing qualities, and he (Mr. Nursey) had tried many such. It, however, resolved itself into a question of cost, and if good rubber was wanted it could always be had by paying a fair price for it. There was plenty of rubber to be had capable of withstanding a more deleterious action than that of sea-water.

Mr. Cargill, in reply, observed that the discussion had turned very much upon the efficiency of the spring moorings which were proposed for the floating breakwater. The character of the springs, however, had been amply established in connection with the navy, and, as an engineer, he should not hesitate in applying them as proposed. With regard to the objection taken to wrought iron for the structure, he would only observe that it was well known that wrought iron endured for years in sea-water or in river-water, provided certain precautions were taken. With cast iron the case was different; for although after some years' immersion in water it might be sound, yet twenty-six years was almost the longest time that cast iron had been found to remain intact in sea-water; and that was good hard grey metal. Inferior iron would not stand nearly so long; therefore to think of using wood for a permanent structure was out of the question altogether. Mr. Pendred said that breakwaters would naturally take their own form—the floating. In the present instance the breakwater had the form which years of experience had shown to be the best. It had first a long slope, and then it approached more to the vertical, and at last became vertical. Harbour engineers, and others who had studied the question, and knew practically the difference between the vertical wall system and the long slope system, had given, most decidedly, the preference to the vertical wall system as best adapted to resist the waves. Plymouth breakwater had a long slope, and it cost 15,000*l.* a year to keep it in repair, besides which it absorbed an enormous amount of material, so that, unless the stone was very plentiful, it would be impossible to maintain it. But where material could not be had the other system must be used, as at Dover. Mr. Jacob had referred to the action of the rise and fall of the tide on the moorings. He (Mr. Cargill) thought the greatest rise and fall of the tide anywhere was 45 feet—that was speaking from memory. The result of that would be, that at high tide the chains would be taut, while at low water they would be slack; and the whole breakwater would drift some little distance, which would be of no consequence. With regard to Mr. Jacob's observation as to having permanent works from the shore, through shallow into deep water, to lead to the floating breakwater, he (Mr. Cargill) thought that in the majority of cases the breakwater would not be connected with the land at all. Plymouth breakwater and several others were built out in the open sea; and there was no connection between them and the mainland whatever. In some cases the floating breakwater might be connected with the land if required, a masonry pier being built out into deep water; but such a requirement would be very rare. Mr. Williams asked the weight of the breakwater. The weight of one section, 100 feet long, accurately taken out, was, as near as possible, 50 tons, inclusive of moorings. That was half a ton per foot run. Mr. Houghton had expressed a doubt as to the efficiency of the moorings. That doubt had also been expressed by other speakers. That arose from the fact that a proper distinction had not been drawn between the moorings of ships and those of the breakwater. They were, however, two very distinct matters, and as far as the moorings of the breakwater were concerned, he (Mr. Cargill) was satisfied that they would prove efficient in practice.

Mr. Halpin had asked whether there was any special reason for the shape which had been adopted in the pontoons. The cylindrical form had been decided upon for reasons of economy. Any other form might be used, but that adopted in the design required the least material. Estimates had been prepared for other sections, and it was found that by using the rectangular, as suggested by Mr. Halpin, four angle-irons at the least would have to be used, which would materially increase the weight, and probably the cost. With regard to the position of the screens, it might perhaps be more advantageous to have them placed at an angle.

The durability of the india-rubber springs had been questioned by Mr. Colyer, but as there was undoubted testimony of their value and durability he (Mr. Cargill) would not refer to them further, especially as, after all, they were more or less only adjuncts of the breakwater. It had been proposed that the apex of the triangle should be towards the sea. That would be a long slope breakwater at once, an arrangement that had been abandoned. It was argued that the sea should run up the slope, but the design of the breakwater was to prevent that running of the water up a slope. The water should be strained off through the successive interstices of the breakwater, so that it might be quieted gradually till it lost all its force. The cost per foot run of the breakwater would depend greatly upon the price of iron. At the present time the cost would approximately be 20*l.* per foot run, delivered in the Thames, and inclusive of moorings.

It had been argued that because ships parted their cables the breakwater would be likely to part from its moorings. But the fact was, that the strain was brought suddenly upon a ship's cable by reason of the vessel being a solid body, whilst the breakwater was a perforated body, which opposed but little resistance to the waves, and consequently brought but little strain upon its cables, and that little was absorbed by the springs. The arrangement of buffers, as mentioned by Mr. Pendred, was not a case in point, as they offered a solid resistance to the force of the waves, whilst the breakwater acted as a screen. With regard to the arrangement of a breakwater consisting of several sections, it was an open question whether they should be connected together or not.

The VICE-PRESIDENT, in closing the discussion, observed that the general opinion appeared to be that there were two main difficulties attendant upon the practical adoption of the floating breakwater, and those were the moorings, and the clashing together of several parts of the structure when several sections were used. But the sections were of considerable length—100 feet each—and the evil apprehended from clashing would be very small well out from land, if they were properly arranged with regard to their distances apart. They would probably not move at all, or not to any very great extent. They would keep where they were, because the waves affecting them would be simply waves of oscillation and not of translation. But if they were very near the coast, they would be affected by currents and tides, and various changes in the conditions of the water which would involve some amount of motion, and require extra care in their arrangement. With regard to the position of the breakwater with respect to the waves, its proper position was unquestionably that assigned to it by the author of the paper. By reversing it, and placing the face of the incline in a direction to meet the waves, would be simply creating the very force which it was wished to avoid. It would be changing the wave of oscillation into one of translation. The question of the moorings was a very important one, and one, moreover, which could hardly be settled in tidal waters without some practical experience with a breakwater on the principle which had been so well discussed.

THE END.

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